2006 IEEE Aerospace Conference Digest

Big Sky, Montana, March 4-11, 2006

Dear 2006 IEEE Aerospace Conference Attendee,

The Technical Program Committee and the Track and Session Organizers are pleased to bring you the technical program for 2006. Covering a wide range of topics in aerospace engineering, science and technology, the program consists of papers delivered in 113 sessions organized into 14 tracks, presented either orally or in our Electronic Presentation Hall over six days. With seven panels, seven plenaries, and invited speakers the total of papers and speakers will be over 520. We expect nearly 700 attendees over the week.

The seven panels this year will address contemporary topics including space engineering workforce, planet finding, robotic history at JPL, developments in space robotics, beyond Einstein, spacecraft autonomy, and NASA-industry partnerships.

Our seven plenary talks promise to be as interesting and exciting as ever, addressing nanotechnology, fusion, responsive space systems, hurricanes, dinosaurs, the Spitzer space telescope, and space tourism.

As hoped, this year we have increased representation from around the world and across industry, government, and academia. Nineteen countries have submitted seventy-two papers and speakers. More than sixty-five universities are represented, as are a dozen national and six international laboratories, nine NASA centers, three military organizations, and nearly 100 commercial companies.

We are confident that you will enjoy the conference and expect that you will take the opportunity to get to know some of your colleagues from this rich, diverse set of attendees.

Ed Bryan
Karen Profet
Richard Mattingly
Technical Program Co-Chairs

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Track 1: Science & Aerospace Frontiers (Plenary Sessions)

Track Organizer: David Woerner, Jet Propulsion Laboratory, Caltech

1.1 Plenary 1: Nanotube-based Molecular Motors

Dr. Alex Zettl (University of California at Berkeley and Lawrence Berkeley National Laboratory)

The design, construction, and operation of electrically-driven molecular actuators and motors using nanotubes as integral components is a leading-edge endeavor in science and engineering. One design uses a multi-wall carbon nanotube as a rotational bearing, allowing low-level voltages to fully control the angular position of a metal plate rotor. This motor, of size ~200nm on a side, is integrated on a silicon chip. Aligned arrays of such motors have been produced. Other successful designs are based on surface-tension-driven liquid metal nanodroplet relaxation oscillators or solid state nanocrystals, with carbon nanotubes playing central functional roles. This presentation addresses the novel underlying physics, energy dissipation, and possible applications of both rotational and linear molecular motors.

1.2 Plenary 2: Operationally Responsive Space

Brig. General Neil McCasland (Space and Missle Systems Center)

Operationally Responsive Space is an effort to make space capabilities more dynamic. Space systems are sophisticated systems and we must address the challenge of making them more responsive from a broader perspective. We can look to the command and control structure for how we schedule, allocate and task services. For other capabilities, we focus on new systems and platforms. In the long term some of these capabilities may benefit from a more consumable approach of the launch-on-demand of dedicated platforms. Shortening the development timeline and reducing the cost to provide new capabilities will allow us to respond more quickly to the problems of the 21st century. General McCasland will present these opportunities with the goal of fostering broad dialog.

1.3 Plenary 3: The World's Largest Laser

Dr. Edward Moses (National Ignition Facility, Lawrence Livermore National Laboratory)

The National Ignition Facility (NIF) is a 192-beam laser facility presently under construction at Lawrence Livermore National Laboratory (LLNL). When completed, NIF will be a 1.8-MJ, 500-TW ultraviolet laser system, by far the most powerful of its kind. The goals for this system are to obtain fusion ignition and to perform high-energy-density experiments in support of strategic security, energy security and material science under extreme pressure and temperature conditions. The NIF is now over 80% complete and has demonstrated that it will meet its performance goals, including flexibility for pulse shaping, pointing, timing, and beam conditioning. NIF has also performed four important experimental campaigns for inertial confinement fusion and high-energy-density science. Presently, the project is installing production hardware to complete the project in 2009, with the goal to begin ignition experiments in 2010. An integrated plan has been developed including the NIF operations, target diagnostics and cryogenic target capability. The experiments are planned using the world's largest computers. This talk will provide information on the NIF Project status, the plan to complete NIF, and the path to ignition.

1.4 Plenary 4: Hurricanes: Natures Dangerous Beauties

Dr. Greg Holland (National Center for Atmospheric Research)

From a fluid dynamics viewpoint, hurricanes are a fascinating and intricate system. But, as we have found out on several occasions over the past couple of years, they pack a wallop, especially for vulnerable communities that have neglected to take proper precautions. As a result, they are amongst the most studied of atmospheric phenomena, and a sophisticated array of technology is deployed to support their analysis and forecasting. I will provide an overview of what gets them going, how they move, the damage that they can cause, whether they are undergoing climatic changes, and the approaches to observing and forecasting them.

1.5 Plenary 5: A Microscopic View of Dinosaurs

Dr. John "Jack" Horner (Montana State University and Museum of the Rockies)

Most people can stand comfortably under the jawline of a mounted Tyrannosaurus rex or walk under the rib cage of a Brachiosaurus without bumping their heads. T. rex is as big as the largest known African elephant, and Brachiosaurus, like other great sauropods, was much larger than any land animal alive today. We are so used to the enormous size of dinosaurs that we almost forget to think about how they grew to be so large. How long did it take them, and how long did they live? And does the way they grew tell us about the way their bodies worked?

Until recently, we had no way to measure age in a dinosaur. Paleontologists had generally assumed that because dinosaurs were reptiles, they probably grew much as reptiles do today--that is, rather slowly. This presentation will discuss how growth rates and physiology is determined, and the latest results from soft tissue finds in T. rex fossils.

1.6 Plenary 6: The Spitzer Space Telescope: The Infrared Universe Revealed

Dr. Michael Werner (Jet Propulsion Laboratory)

The launch of the Spitzer Space Telescope – NASA's Great Observatory for Infrared Astronomy - in August '03 provided the international scientific community with the most powerful tool yet available for probing the cosmos at infrared wavelengths between 3.6 and 160um. Spitzer combines the intrinsic sensitivity of a cryogenic space telescope with the imaging and spectroscopic power of modern infrared detector arrays. Spitzer also pioneers a number of technical and operational innovations which have been enthusiastically adopted by many current and upcoming missions. Spitzer addresses the biggest questions facing modern astrophysics: Where Do We Come From? Are We Alone? To address our origins, Spitzer carries out deep surveys of the distant Universe, finding mature, massive galaxies whose characteristics challenge our understanding of galaxy formation. To address our uniqueness, Spitzer studies the formation and evolution of stars and planetary systems and has provided the first detection of light from planets orbiting other stars. Spitzer Project Scientist Michael Werner will report on the scientific highlights from Spitzer to date and describe the challenges and opportunities facing the observatory during the remaining 3+ years of its cryogenic mission.

1.7 Plenary 7: Project Starchaser

Steve Bennett (Starchaser Industries)

Founded in 1992, Starchaser is a privately held company with a research & development and assembly and integration facility near Manchester in the UK. On 22nd November 2001 Starchaser Industries successfully launched Nova, the first privately built rocket in the world capable of carrying people into space. Current R&D projects include the development of a reusable 15-tonne thrust rocket engine, a semi-reusable micro-satellite launch system and a sub-orbital spaceship for space tourism applications. The company has also recently expanded activities to New Mexico where Starchaser has a view to launching out of the up and coming Southwest Regional Spaceport. Steve Bennett will present an overview of the Starchaser project with particular reference to the company's activities in the development of a low cost reusable launch vehicle for space tourism applications.

Track 2: Space Missions, Systems, and Architecture

Track Organizer: Christopher Stevens, Jet Propulsion Laboratory
Track Organizer: Marina Ruggieri, University of Roma Tor Vergata

2.01 Mobility and Robotics Systems for In Situ Exploration

Session Organizer: Wayne Zimmerman, Jet Propulsion Laboratory, Caltech

2.0101 SILVRCLAW II Analysis, Prototype Development, and Testing

Greg S. Mungas (Jet Propulsion Laboratory), Dimi Apostolopoulos (Carnegie Mellon Robotics Institute), David Fisher (Firestar Engineering, LLC), Chris Mungas (Firestar Engineering, LLC), Stuart Heys (ProtoInnovations, LLC), Michael Wagner (ProtoInnovations, LLC), Benjamin Carryer (Firestar Engineering, LLC), James Teza (ProtoInnovations, LLC)

SILVRCLAW (Stowable, Inflatable, Large, Vectran, Rigidizable, Cold-resistant, Lightweight, All-terrain Wheel) is an inflatable, rigidizable wheel technology that enables compact robotic vehicles with significant ground clearance. Such a vehicle could traverse aggressive rocky terrains, travel over chasms with 1m separation, and offer the mission operator the ability to navigate with orbital-imagery resolutions. We have confirmed that a prototype wheel design allows large wheel loads of up to hundreds of kilograms per wheel in Mars equivalent gravity and consumes very little energy (less than 100Whr/km). We discuss the ongoing analysis, prototype development, and recent testbed results of the SILVRCLAW wheel.

2.0102 Improved Target Handoff for Single Cycle Instrument Placement

Richard Madison (Jet Propulsion Laboratory)

Single Cycle Instrument Placement (SCIP) could dramatically accelerate various planetary rover operations. A SCIP implementation being validated at JPL visually tracks the placement target while approaching it. The implementation hands the tracking off to wider field-of-view cameras twic during the approach. We investigated the amount of tracking error introduced by various handoff methods. Three methods averaged 1-pixel error when successful but only worked in half of the tests. Two methods reliably produced about 10 pixels of error. None reliably reached the goal of 1 cm (about 4 pixel) handoff accuracy.

2.0103 Humanoids in support of Lunar and Planetary Surface Operations

Adrian Stoica, Didier Keymeulen (Jet Propulsion Laboratory)

This paper presents a vision of humanoid robots as human's key partners in future space exploration, in particular for construction, maintenance/repair and operation of lunar/planetary habitats, bases and settlements. It integrates this vision with the recent plans for human and robotic exploration, aligning a set of milestones for operational capability of humanoids with the schedule for the next decades and development spirals in the Project Constellation. . A pilot project using small-scale Fujitsu HOAP-2 humanoid is outlined.

2.0104 Mobile Science Platforms for Impassable Terrain

Michael L. Rilee (L-3 Communications GSI)

Some of the most scientifically interesting terrain is among the most inaccessible, presenting problems for all mobility strategies. In this work we discuss a scalable, parallel system of reconfigurable members integrated as a three-dimensional tetrahedral mesh of actuators and structural elements. These robots move by adapting themselves to the irregularities of their environment. Prototypes of these parallel tetrahedral robots, e.g. the 12-TET Rover "Arnold," are being developed at Goddard Space Flight Center. We discuss our experience with the architecture.

2.0105 The Mars Exploration Rover Surface Mobility Flight Software: Driving Ambition

Mark W. Maimone, Jeffrey J. Biesiadecki (Jet Propulsion Lab)

NASA successfully landed two mobile robot geologists on the surface of Mars in January 2004: the Spirit and Opportunity Mars Exploration Rovers (MER). Although the achievement of their successful landings stands out as a technological tour de force, it is

their ability to traverse while on the surface of Mars that has enabled both rovers to succeed in their primary goals. In this paper we describe the software that has driven these rovers more than a combined 11,000 meters over the Martian surface, including its design and implementation, and summarize current mobility performance results from Mars.

2.0106 A Comparison of Force Sensing Techniques for Planetary Manipulation

Daniel Helmick, Avi Okon, and Matt DiCicco (Jet Propulsion Laboratory)

Five techniques for sensing forces with a manipulator are compared analytically and experimentally. The techniques compared are: a six-axis wrist force/torque sensor, joint torque sensors, link strain gauges, motor current sensors, and flexibility modeling. The accuracy and repeatability of each technique is quantified and compared. The relative complexity and the impact on flight design of each technique are also compared. The results presented can be used in a trade study for missions requiring manipulator force sensing capabilities.

2.0107 Concept for Coring from a Low-mass Rover

Paul Backes, Antonio Diaz-Calderon, Curtis Collins, Zensheu Chang (Jet Propulsion Laboratory); Oussama Khatib, James Warren (Stanford University)

Future Mars missions, such as the Mars Sample Return (MSR) mission, may benefit from core sample acquisition from a low-mass rover where the rover cannot be assumed to be stationary during a coring operation. An MSR mission scenario with a low-mass rover has been developed and the technology needs have been investigated. Models for alternative types of coring tools have been developed and input along with wheel-soil interaction models into the Stanford Simulation & Active Interfaces (SAI) simulation environment to enable simulation of coring operations from a rover. Current results of the models, simulation, and coring tests are provided.

2.0108 Vision-Based End-Effector Position Error Compensation

Max Bajracharya, Matthew DiCicco, Paul Backes (Jet Propulsion Laboratory)

This paper describes a computationally efficient algorithm that provides the ability to accurately place an arm end-effector on a target designated in an image using low speed feedback from a fixed stereo camera. The algorithm is robust to visual occlusion of the end-effector and does not require high fidelity calibration of either the arm or stereo camera. The algorithm works by maintaining an error vector between the location of a fiducial on the arm`s end-effector as predicted by a kinematic model of the arm and detected and triangulated by a stereo camera pair. It then uses this error vector to...

2.02 Future Space and Earth Science Missions

Session Organizer: Filippo Graziani, University of Rome
Session Organizer: Robert Gershman, Jet Propulsion Laboratory, Caltech

2.0201 Global Precipitation Measurement Mission Architecture and Mission Concept

David Bundas (NASA Goddard Space Flight Center)

The Global Precipitation Measurement (GPM) Mission is a collaboration between the NASA, JAXA, and other US and international partners, with the goal of monitoring the diurnal and seasonal variations in precipitation over the surface of the earth. These measurements will be used to improve current climate models and weather forecasting, and enable improved storm and flood warnings. This paper gives an overview of the mission architecture and addresses some of the key trades that have been completed, including the selection of the Core Observatory's orbit, orbit maintenance trades, and design issues related to meeting orbital debris requirements.

2.0202 Herschel/Planck Program Spacecraft Design Solutions for two Science Missions

Astrid Heske, Thomas Passvogel, Gerald Crone (ESTEC, ESA), Jean-Jacques Juillet, Bernard Collaudin, Pascal Rideau (Alcatel Alenia Space)

The two science missions Herschel and Planck are combined in one science program of the European Space Agency (ESA). Herschel targets the sub-millimeter spectrum (60 to 670 microns) to explore the formation of galaxies and stars. Planck will survey the whole sky simultaneously in nine frequency channels (30 to 900 GHz) to unravel the temperature fluctuations of the cosmic background radiation. The design solutions adopted for each spacecraft, given the challenging payload requirements, will be presented. Both spacecraft will be launched from Kourou, French Guiana, on an Ariane 5 end of 2007 to L2 of the Earth-Sun system.

2.0203 An Architecture Program for the Robotic Exploration of Venus

Juan Martín Canales-Romero (German Space Operations Center - DLR); Adnan Shear Khan, Jonas Jonsson (International Space University, Summer Session Program 2005)

To date, most space exploration has focused on the outer Solar System while the inner Solar System between Earth and the Sun has received only limited attention. In this region, Venus, with a similar size to Earth but with a very different environment, is probably the most interesting body. The environment of Venus is sufficiently challenging as to preclude the possibility of human presence. Consequently, robotic exploration is required. Taking this into account the participants of the International Space University SSP 2005 decided to develop an architecture program for robotic missions to Venus. This program extends from 2005 - 2050.

2.0204 Exploring the Possibilities: Earth and Space Science Missions in the Context of Exploration

Michael Calabrese (SGT Inc.); Barbara Pfarr (NASA/Goddard); James Kirkpatrick (AAS); Jonathan Malay (Lockheed Martin)

At the American Astronautical Society's 43rd Annual Robert H. Goddard Memorial Symposium it was apparent that NASA's Exploration Initiative is tightly coupled to multiple scientific initiatives: exploration will enable new science and science will enable exploration. NASA's Science Mission Directorate plans to develop science missions that deliver science that is vital, compelling and urgent. This paper will attempt to show that science plays a key role in exploration by I summarizing the key scientific questions, the space and Earth science missions proposed to answer them, the key technologies that will enable these missions, and developments and achievements since the Symposium.

2.0205 Navigator Program: Exploring New Worlds

Peter R. Lawson (Jet Propulsion Laboratory)

NASA`s Navigator Program is a series of interrelated missions to explore and characterize new worlds. Are there other solar systems like our own? Are there other habitable worlds? Is there life elsewhere in the universe? These are the questions that the Navigator Program seeks to address. The program and its missions are described in this paper.

2.0206 Design of a Long Endurance Titan VTOL Vehicle

Ravi Prakash, Robert D. Braun, Luke S. Colby, Scott R. Francis, Mustafa E. Gündüz, Kevin W. Flaherty, Jarret M. Lafleur (Jet Propulsion Laboratory); Henry S. Wright (NASA Langley)

A vertical takeoff and landing (VTOL) vehicle was designed to conduct a scientific investigation of Saturn's moon Titan. A helicopter was baselined because of its many advantages over other types of vehicles. The required 1.9 kW is produced by a turbo expander cycle, which utilizes a nuclear power source and the atmosphere of Titan. The turbo expander engine can revolutionize planetary aerial flight so that the limiting factor for the mission life is not available power but the life of the mechanical parts. This design is the first to investigate the implications of this technology on a Titan aerial vehicle.

2.0207 GeoSTAR: Developing A New Payload for GOES Satellites

Bjorn Lambrigtsen (Jet Propulsion Laboratory)

GeoSTAR is a new microwave sounder concept intended for the GOES-R series of satellites, using aperture synthesis to attain a large aperture. It will fill a gap in our remote sensing capabilities and enable important Earth observations that are not currently possible, such as all-weather temperature and water vapor soundings and rapid-cycle rain mapping. A fully functional proof of concept prototype has been developed at JPL, test measurements show that the system works as designed, and the first successful 2D synthesis image reconstruction has been achieved. An effort is now under way to identify funding for a space mission.

2.0208 Architecting Space Exploration Campaigns: A Decision-Analytic Approach

Erin Baker (University of Massachusetts); Elisabeth Morse, Andrew Gray, Robert Easter (NASA (Jet Propulsion Laboratory)

Under its Vision for Space Exploration, NASA is moving from designing single space missions to architecting exploration campaigns. In comparing campaign options, assessing the value of flexibility to respond to future discoveries and adapt to uncertainties is critical. This paper shows the benefits of Decision Analysis for campaign design and evaluation. Important concepts of decision analysis are reviewed through the lens of designing a campaign to find exploitable equatorial water on Mars. The method is general to any search campaign. The paper concludes with a discussion of the challenges and opportunities in applying similar techniques to other types of campaigns.

2.0209 Human Spaceflights Will Extend Regulatory and Legal Framework Governing Civil Aviation

Mariagrazia Spada

Sub orbital flights offer an important approach to the evolution of the market and demonstrate the safety of space flights and the profitability of space tourism. By contrast, aviation is a global industry, largely commercial, involving the range of activities from engineering design to marketing. Aviation has very high safety levels developed over decades of experience carrying billions of passengers. This paper will consider briefly the expansion of the Airspace System concept to include commercial space operations as an integral component, highlighting legal concepts learned in the frame of the modernization of the civil aviation regime and of the outer space Law...

2.03 Missions and Technologies for In Situ Exploration and Sample Return

Session Organizer: Patricia Beauchamp, Jet Propulsion Laboratory, Caltech

2.0301 What Titan is Really Like: In-Situ Measurements of the Titan Environment by the Huygens Probe

Ralph Lorenz (LPL, U. Arizona)

The dramatic findings of the Cassini mission, and especially the Huygens probe, at Titan confirm it to be a planetary target of great interest in many scientific fields. This paper reviews in particular the meteorological and geological results of Huygens as they pertain to future mission...

2.0302 Mars Ascent Vehicle: Key Elements of a Sample Return Mission

David D Stephenson (NASA Marshall Space Flight Center); Harvey J. Willenberg (Gray Research, Inc.)

A Mars Ascent Vehicle (MAV) will be brought to the Martian surface within a Mars Sample Return lander; receive samples delivered by a mobile surface vehicle; and launch the samples into Mars orbit for return to Earth. Key features of the MAV operations and design are discussed, including the thermal, environmental, and structural requirements and their conceptual design solutions during each phase; concepts for insertion of the orbiting sample into the payload bay inside the launch tube; and pre-launch operations. MAV launch to orbit details will be discussed, and key technology development challenges will be identified.

2.0303 Construction and Resource Utilization eXplorer (CRUX)

Albert F. C. Haldemann (Jet Propulsion Laboratory); Jerome B. Johnson (USA ERDC-CRREL); Richard C. Elphic (Los Alamos National Laboratory), William V. Boynton (University of Arizona); John Wetzel (Applied Research Associates).)

CRUX is a modular suite of geophysical and borehole instruments combined with display and decision support system (Mapper/DSS) tools to characterize regolith resources, surface conditions, and geotechnical properties. CRUX is a NASA-funded effort to provide enabling technology for Lunar and Planetary Surface Operations. The Mapper/DSS uses data fusion to uniquely provide regolith information. To demonstrate, we show how it applies to mapping distribution and form of lunar polar hydrogen with selected CRUX instruments: Borehole Neutron Probe and Thermal Evolved Gas Analyzer data versus depth join Surface Neutron Probe data for 3D information. Secondary instruments and physical models improv the characterization.

2.0304 Planning for Planetary Protection and Contamination Control: Challenges Beyond Mars

Andrea P. Belz, James A. Cutts (Jet Propulsion Laboratory)

In situ analysis for targets beyond Mars brings new challenges in planetary protection and contamination control. Current NASA plans include missions to bodies of interest for life-detection or prebiotic science, including Europa, Titan, and comets. These targets present challenges because NASA policies specify new requirements for missions to Europa, and new guidelines for Titan are anticipated; furthermore, the comet missions have additional significance as sample return missions. This document summarizes the technical challenges to planetary protection and contamination control for these targets of interest and outlines some of the system-level considerations in designing an appropriate technology investment strategy.

2.0305 Design Tools for Cost-Effective Implementation of Planetary Protection Requirements

Louise Hamlin, Andrea Belz, Michael Evans, Jason Kastner, Celeste Satter, Andy Spry (Jet Propulsion Laboratory)

Since the Viking missions to Mars in the 1970s, accounting for the costs associated with planetary protection implementation has not been done systematically during early project formulation phases, leading to unanticipated costs during subsequent implementation phases of flight projects. In the intervening period, more rigorous planetary protection requirements, resulting from new knowledge about the limits of life on Earth, have been developed. This, together with current plans to conduct life-detection experiments on a number of different solar system target bodies is motivated a systematic approach to integrating planetary protection requirements and mission design. A current development effort at NASA`s Jet...

2.0306 Cleaning to Achieve Sterility

Roger Kern, Larry Kirschner, Myron La Duc, Fei Chen, and Kasthuri Venkateswaran (Jet Propulsion Laboratory)

NASA Planetary Protection regulations state that a surface may be considered “sterile” if a microbial burden of less than 300 aerobic bacterial spores per square meter can be further treated to achieve a 104 fold reduction in viable endospores (spores). The results of previous studies, have suggested that surfaces might be cleaned to a level that is essentially sterile. Here, we report the results of a comparative analysis of the efficacy/ability of three different cleaning approaches to remove bacterial spores from a series of surrogate spacecraft surfaces. In order to accomplish the most realistic and reproducible spore deposition...

2.0307 A Rapid Micro-Detection System for the Enumeration of Bacterial Endospores

Fei Chen, Gayane A. Kazarians, Kasthuri Venkateswaran, and Roger Kern (Jet Propulsion Laboratory)

NASA continuously monitors spacecraft surfaces to assure a very low presence of bacterial endospores upon landing on the surface of Mars. In order to meet the rigid schedules of spacecraft assembly, a more rapid, sensitive spore detection assay is being considered as

an alternate method to the current three-day NASA standard culture-based assay. The Millipore MicroStar Rapid System (RMDS) has been used successfully for rapid bioburden enumeration in a wide range of applications. It combines membrane filtration, adenosine triphosphate (ATP) bioluminescence chemistry, and image analysis based on photon detection with a Charge Coupled Device (CCD) camera. The RMDS is rapid...

2.0308 Electron Beam (10 MeV) Irradiation to Decontaminate Spacecraft Components for Planetary Protection

Suresh D. Pillai, Martha Cepeda, Kamlesh Soni, Sarah Mittasch, and Joe Maxim (Texas A&M University); Kasthuri Venkateswaran, and Shariff Osman (Jet Propulsion Laboratory)

Spacecraft and payloads are made up of a diverse set of materials and components, many of which are sensitive to heat and undergo deterioration during dry heat sterilization. Thus, there is a need to develop alternate spacecraft sterilizing technologies for planetary protection. Electron beam irradiation using 10 MeV linear accelerators was found to be capable of a 6-log reduction of different Bacillus spores on aluminum/titanium coupons at 30KGy.These studies suggest that E-beam sterilization has value as as planetary protection technology.

2.0309 Preventing the Forward Contamination of Mars

John D Rummel (NASA HQ)

We have determined that standing liquid water existed on Mars for long periods of time in the past, and we continue to uncover evidence about past water, ice, and the dynamic nature of the planet. A recent NRC report recommended measures to prevent future missions from contaminating Mars and allow continued astrobiological exploration. Interim requirements recommended by them include surface-sterilization of all spacecraft landing on Mars until “special” regions on Mars can be objectively differentiated from “non-special” regions. This paper will discuss the report, its application to future missions, and actions required to support the continuing exploration of Mars.

2.04 Deep Space, Earth and Discovery Missions

Session Organizer: Brian Muirhead, Jet Propulsion Laboratory, Caltech
Session Organizer: James Graf, Jet Propulsion Laboratory, Caltech
Session Organizer: Joseph Burt, NASA/Goddard Space Flight Center
Session Organizer: W. Adams, NASA Goddard Space Flight Center

2.0401 The Glory Program: Global Science from a Unique Spacecraft Integration

Jaya Bajpayee (NASA Goddard Space Flight Center), Darcie Durham, Tom Itchkawich (Orbital Sciences)

The Glory program is an Earth and Solar science mission designed to broaden science community knowledge of the environment. The causes and effects of global warming have become a concern in recent years and Glory aims to contribute to the knowledge base of the science community. Glory is designed for two functions: one is solar viewing to monitor the total solar irradiance and the other is observing the Earth’s atmosphere for aerosol composition. The former is done with an active cavity radiometer, while the latter is accomplished with an aerosol polarimeter sensor to discern atmospheric particles. The Glory program is managed...

2.0402 James Webb Space Telescope (JWST) Project Overview

Phil Sabelhaus (NASA Goddard Space Flight Center)

The James Webb Space Telescope (JWST) project at the NASA, Goddard Space Flight Center (GSFC) is responsible for the development, launch, flight, and science operations for the telescope. The project is in Phase B with its launch scheduled for no earlier than June 2013. The project is a partnership among NASA, the European Space Agency (ESA), and the Canadian Space Agency (CSA). The JWST mission team is fully in place, including major ESA and CSA subcontractors. This paper provides an overview of the planned JWST science, current architecture focusing on the instrumentation, and mission status, including technology developments and risks.

2.0403 Return to Mercury: The MESSENGER Spacecraft and Mission

Robin M. Vaughan, James C. Leary, Richard F. Conde, George Dakermanji, Carl J. Ercol, Karl B. Fielhauer, David G. Grant, Theodore J. Hartka, T. Adrian Hill, Steven E. Jaskulek, James V. McAdams, M. Annette Mirantes, David F. Persons, and Dipak K. Srinivasan (The Johns Hopkins University Applied Physics Laboratory)

MESSENGER is the seventh NASA Discovery mission and will be the first Mercury orbiter. MESSENGER was launched on August 3, 2004, and performed its single Earth flyby on August 2, 2005. The spacecraft will make two flybys of Venus and three of Mercury prior to orbiting Mercury for one Earth-year beginning in March 2011. The spacecraft design features a large sunshade that protects the main bus and instruments from intense solar heat and radiation. Seven miniaturized science instruments, along with the antennas, will globally characterize Mercury's composition, structure, atmosphere, and charged particle environment.

2.0404 The U.S. Rosetta Project: Eighteen Months in Flight

C. Alexander, S. Gulkis, M. Frerking, D. Holmes, P. Weissman (Jet Propulsion Laboratory);,), J. Burch, A. Stern, R. Goldstein, J. Parker (Southwest Research Institute), T. Cravens (University of Kansas), S. Fuselier (Lockheed Martin); Advanced Technology Center), T. Gombosi (University of Michigan), P. Ferri, E. Montagnon (European Space Agency)

The International Rosetta Mission, 3rd cornerstone mission of the European Space Agency (ESA) has been in operations since March 2, 2004. This year, Rosetta conducted observations of comet 9P/Tempel 1 in support of NASA`s Deep Impact mission. In this paper we will update the status of the instruments following the commissioning exercise, an exercise that was only partially complete when a report was prepared for the 2005 IEEE conference. We will present an overview of the 2005 Earth/Moon activities and NASA's Deep Space Network support for an ESA request for Delta Difference One-Way Ranging in support of the Mars encounter.

2.0405 Phoenix - The First Mars Scout Mission (A Mid-Term Report)

Barry Goldstein, Robert Shotwell (Jet Propulsion Laboratory)

As the first of the new Mars Scouts missions, the Phoenix project was selected by NASA in August of 2003. Over its initial 18 months, the project has completed its advertised formulation phase activities, and has recently been approved for continuation to formulation, culminating in a launch planned for August 3, 2007. This paper will cover the mission design, progress made in the formulation phases, key system trades, future plans and challenges.

2.05 Advanced Constellation Concepts and Missions

Session Organizer: Maurice Martin, Air Force Research Laboratory

2.0501 Demonstration and Science Experiments for DoD Space Capability in the MEO.

Greg Spanjers, James Winter (Air Force Research Laboratory), Dan Cohen (Sequoia Tech), Aaron Adler, Jason Guarnieri (Jackson & Tull), Martin Tolliver, Greg Ginet, Bronek Dichter (Air Force Research Laboratory); Jeff Summers (MicroSat Systems)

The Air Force Research Laboratory (AFRL) Space Vehicles Directorate has developed the Demonstration and Sciences Experiment (DSX) to research the technologies needed to deploy space assets in the harsh MEO radiation environment. The DSX comprises three basic research experiments: 1) Wave Particle Interaction Experiment, 2) Space Weather Experiment, and 3) Space Environmental Effects Experiment.

2.06 Instruments for In Situ Exploration

Session Organizer: Martin Buehler, Jet Propulsion Laboratory, Caltech
Session Organizer: Richard Dissly, Ball Aerospace & Technologies Corp

2.0601 Surface and Borehole Neutron Probes for the Construction and Resource Utilization eXplorer (CRUX)

Richard C. Elphic, Sangkoo Hahn, David J. Lawrence, William C. Feldman (Los Alamos National Lab); Jerome B. Johnson (ERDC-Cold Regions and Engineering Laboratory); Albert F. C. Haldemann (NASA (Jet Propulsion Laboratory)

The CRUX surface and borehole neutron probes detect and assay near-surface hydrogen-bearing resources at the Moon and Mars. The surface neutron probe is used aboard a rover to prospect for water ice or other hydrogenous materials near the surface. The borehole neutron probe is integrated into a drill string segment and provides subsurface stratigraphy of hydrogenous layers. We report on experiments that we have performed to demonstrate the instruments` effectiveness.

2.0602 Electrical Properties Cup (EPC) for Characterizing Water Content of Martian and Lunar Soils

Martin Buehler (Jet Propulsion Laboratory)

In this effort we used electrical impedance spectroscopy and a four-probe apparatus, the Electrical Properties Cup (EPC), to measure the properties of various soils lunar and martian soil simulants. The impedance values are characterized by a resistance-capacitor network that is used to determine the soil conductivity and dielectric constant. This presentation describes the experimental four-probe apparatus, procedures used to prepare the samples including soil washing and loading, and soil impedance measurements.

2.0603 A Seismic Profiler for the Construction and Resource Utilization Explorer (CRUX)

Donald G. Albert (USA ERDC-CRREL) and W. Bruce Banerdt (Jet Propulsion Laboratory)

A modular integrated suite of instruments and software known as the Construction Resource Utilization Explorer is being developed for NASA to provide semiautonomous reconnaissance of the lunar and planetary surfaces. This paper describes the seismic profiler instrument. The hardware is described and examples of synthetic and real (Earth) seismic data are presented and discussed. Because of the advances in the electronic hardware and digital analysis methods that have occurred since the Apollo lunar missions, this instrument will have the flexibility to gather and analyze seismic data in a number of different ways to enhance the usefulness of the seismic information.

2.0604 Miniature Ground Penetrating Radar, CRUX GPR

Soon Sam Kim, Steven R. Carnes, Albert F. Haldemann (Jet Propulsion Laboratory); Christopher T. Ulmer (Ulmer Systems); Eddie Ho Wah Ng (A Star Technologies); Steven A. Arcone (CRREL)

Under NASA instrument development programs (PIDDP 2000–2002, MIDP 2003–2005, ESR&T, 2005), we have been developing miniature ground penetrating radars (GPR) for use in mapping subsurface stratigraphy from planetary rovers for Mars and lunar applications. As a part of the CRUX (Construction & Resource Utilization Explorer) instrument suite, the CRUX GPR is for a lunar prospecting application for construction operations including ISRU (in-situ resource utilization). Currently, the CRUX GPR (Technology Readiness Level 4) has miniaturized radar electronics (1 W, 45 g), with 2 batteries (9 V) operating at 800-MHz center frequency. Field testing of the prototype has been conducted extensively.

2.0605 Atmospheric Electron-Induced X-ray Spectrometer (AEXS) Development

Jaroslava Z. Wilcox, Eduardo Urgiles, Risaku Toda, and Joy Crisp (Jet Propulsion Laboratory)

AEXS is an electron microprobe based on excitation of XRF spectra using a focused electron beam to perform elemental analysis of samples in ambient atmospheres. The microprobe that has been assembled in our laboratory uses a thin SiN membrane to isolate the vacuum of the electron probe, requires no active pumping (a big step towards the development of a stand-alone instrument), has been in operation for over 1 year, and used

for performing elemental analysis of NIST and USGS standards with good agreement with the certified composition in up to about 90 Torr-cm thick atmospheres.

2.0606 Deployable Wood Wasp Drill for Planetary Subsurface Sampling

Yang Gao, Alex Ellery (University of Surrey); Mustafa Jaddou, Julian Vincent (University of Bath)

Growing interest in planetary subsurface exploration has prompted an examination of advanced drilling technologies. Drawing inspiration from nature for a lightweight and energy efficient solution, we propose a novel drilling method based on the working mechanism of wood wasp ovipositors. The bio-inspired drill requires no reactive external force by applying two-valve-reciprocating motion. This paper presents a conceptual design of the wood wasp drill. Lab-based experiments have shown that the bio-inspired drilling method is feasible and has potential of improving drill efficiency without overhead force or mass.

2.0607 Pulsed Cavity Ringdown Laser Absorption Spectroscopy in a Hollow Waveguide

Greg S. Mungas (Jet Propulsion Laboratory); Chris Dreyer (Colorado School of Mines)

In this paper, we discuss and analyze a new proposed instrument technique for measuring trace gases and isotopic ratios - pulsed cavity ringdown laser absorption spectroscopy in a hollow waveguide (HWP-CRDS). This approach is compared with existing techniques and is shown to offer significant improvements in minimum detection limit, required sample volume, miniature instrument implementation, and rapid measurement times.

2.07 Radiation Issues for Human Spaceflight

Session Organizer: Lawrence Townsend, University of Tennessee

2.0701 Forecasting of Solar Particle Event Integral Proton Fluences Using Bayesian Inference

Lawrence W. Townsend (The University of Tennessee)

Predicting fluences rather than doses allows the forecaster to then calculate and predict the response function of choice. In addition to quantitative forecasts, our models provide almost immediate qualitative classification of new events as significant versus insignificant, thus providing a tool to operators for making decisions concerning the commitment of forecasting resources. The justification for modeling fluence using non-linear sigmoidal growth curves and hierarchical models is examined, and the hypothesis that significant events (in terms of fluence) can be identified by fluence alone, early in the evolution of the event, is examined.

2.0702 Characterization of the Lunar Radiation Environment Using the CRaTER Detector

Lawrence W. Townsend, Hanna M. Moussa, and Youssef Charara (The University of Tennessee)

The LRO mission will conduct exploration-enabling observations. One of the objectives of this mission is to characterize the lunar radiation environment and its biological impacts on humans. CRaTER will directly measure linear energy transfer (LET) spectra, thereby providing a direct link between the ambient environment and its biological impact on future human missions to the Moon. In this presentation an overview of the CRaTER team and project organization will be presented and the current version of the proposed CRaTER instrument will be described. Preliminary computational predictions of some components of the LET spectra will be presented.

2.0703 Electrostatic Active Radiation Shielding Revisited

Ram Tripathi (NASA Langley Research Center)

For the success of NASA's new vision for space exploration to Moon, Mars and beyond, exposures from the hazards of severe space radiation in deep space long duration missions is 'a must solve' problem. Langley has developed state-of-the-art radiation protection and shielding technology for space missions. The present investigation revisits electrostatic active radiation shielding and explores the feasibility of using the electrostatic shielding in concert with the innovative materials shielding and protection technologies. Conclusions are drawn, should the electrostatic shielding be successful, for the future directions of space radiation protection.

2.0704 Effectiveness of Shielding Materials for Dose Reduction

Stephen B. Guetersloh, Cary J. Zeitlin, Lawrence H. Heilbronn, Jack Miller (LBNL)

The design of future spacecraft such as the Crew Exploration Vehicle must take into account the radiation shielding properties of both the structural components as well as dedicated shielding materials. Hydrogenous materials and low-mass elements have been shown to be more effective radiation shields than the aluminum currently used in spacecraft hull design. Polyethylene, CH2, has therefore been chosen by NASA as the reference material for comparison of multi-function composites currently being developed. A wide variety of targets, both elemental and composite, were placed in the particle beams, and the spectra of particles emerging from the targets were measured.

2.0705 Novel Boron Fiber Composites for Radiation Protection

W. Kowbel, C. Bruce and J. C. Withers (MER Corporation); C. Ohlhorst and S. A. Thibeault (NASA LaRC)

Future space systems developed under NASA Space Initiative need to address the issue of radiation protection in conjunction with multifunctional requirements. The state-of-the-art (SOTA) thermal protection systems are based upon low density carbon insulation and phenolic based ablatives. Such systems are not optimized for radiation resistance. A novel approach to thermal protection incorporating radiation protection was developed. This new system is based upon boron-foam with a specifically designed, functionally graded thermal protection system.

2.0706 FLUKA Status and Preliminary Results from the July-2005 AGS Run

Lawrence S. Pinsky (University of Houston)

The FLUKA Monte Carlo code has been modified as part of NASA's Space Radiation Shielding Program for use in simulating the Space Radiation environment. This July data was taken at the AGS along with the groups from LBL and MSFC measuring fragmentation, neutron and secondary charged particle spectra from Fe, Si and C beams at 3, 5 and 10 GeV/A on a variety of targets including C, Al, Fe, Cu and Polyethylene. This energy range is the crossover point in event generator technique and the data will help guide the evolution of the event generators in this crucial region.

2.08 In-Space Technology Validation Missions

Session Organizer: Martin Buehler, Jet Propulsion Laboratory, Caltech
Session Organizer: Raphael Some, Jet Propulsion Labs

2.0801 Technology Validation: NMP ST8 Dependable Multiprocessor Project

John R. Samson, Jr. Jeremy Ramos (Honeywell), Minesh Patel (Tandel Systems, LLC), Alan George (University of Florida), Rafi Some (Jet Propulsion Laboratory)

Dependable Multiprocessor technology is being developed as part of the New Millennium Program (NMP) ST8 (Space Technology 8) project. The objective of this NMP ST8 effort is to combine high performance, fault tolerant, COTS-based cluster processing with replication services, and fault tolerant middleware in an architecture and software framework capable of supporting a wide variety of mission applications. Dependable Multiprocessor technology development is continuing as one of the four selected ST8 flight experiments. This paper describes the validation experiments, demonstrations, and performance achieved to date, and the plans for Dependable Multiprocessor technology flight validation.

2.0802 Formulation Refinement and Access to Space for the ST8 Mission

Philip R. Turner, Linda M. Herrell (Jet Propulsion Laboratory)

NASA`s New Millennium Program (NMP) approach to space flight validation alternates between system and subsystem level missions. The ST8 mission is the second NMP subsystem-level mission and will host 4 technology experiments from 4 different technology areas. This paper tells the story of the steps in formulation refinement leading to the establishment of ST8 as a formal flight project, with some insights and comments on the benefits and risks of the approach.

2.0803 Access to Space for Technology Validation Missions: Exploring Possibilities of Suborbital Flight

Linda Herrell, Xiaoyan Zhou (Jet Propulsion Laboratory)

The underlying purpose of this paper is to bring together information about this well-established suborbital community in juxtaposition with the space community's search for low-cost access to space, and to suggest that a re-introduction of the suborbital capabilities can open up options not considered before. This is an attempt to link two communities, Suborbital and Space, at a time when the cost of access to space and dwindling budgets are motivation enough to re-visit alternatives in the suborbital community. Nothing is new here except the paradigm – including suborbital capabilities in the same venue as space mission design.

2.0804 The Space Technology 8 Mission

Stephen F. Franklin (Jet Propulsion Laboratory)

The Space Technology 8 (ST8) mission is the latest in NASA's New Millennium Program technology demonstration missions. ST8 includes a spacecraft bus built by industry, flying four new technology payloads in low-Earth orbit. This paper will describe each payload, along with a brief description of the mission and spacecraft. The payloads include a miniature loop heat pipe intended to save mass and power on future small satellites, designed and built by NASA's Goddard Space Flight Center; a lightweight, 35g/m linear mass, 40 m deployable boom intended as a future solar sail mast built by ATK Space Systems; a deployable, lightweight...

2.0805 Space Technology 5 - Technology Validation Update

Candace C. Carlisle, Guan Le, James A. Slavin, J. Timothy VanSant, Evan H. Webb (NASA)

The Space Technology 5 (ST5) Project, part of NASA's New Millennium Program, will consist of a constellation of three micro-satellites. The validation objectives are to demonstrate the research-quality science capability of the ST5 spacecraft; to operate the three spacecraft as a constellation; and to design, develop, test and flight-validate three capable micro-satellites with new technologies. The project team has made significant progress in the past year in building and testing the ground system and flight hardware. Through component-level testing and spacecraft integration and test, many components have been demonstrated on the ground to begin achieving the validation objectives.

2.0806 Autonomous Science Agents and Sensor Webs: EO-1 and Beyond

Rob Sherwood, Steve Chien, Daniel Tran, Benjamin Cichy, Rebecca Castano, Ashley Davies, Gregg Rabideau (Jet Propulsion Laboratory);)

An Autonomous Science Agent, part of the New Millennium Space Technology 6 Project is currently flying onboard the Earth Observing One (EO-1) Spacecraft. This software enables the spacecraft to autonomously detect and respond to science events occurring on the Earth. The package includes software systems that perform science data analysis, deliberative planning, and run-time robust execution. This software has demonstrated the potential for space missions to use onboard decision-making to detect, analyze, and respond to science events, and to downlink only the highest value science data. As a result, ground-based mission planning and analysis functions have been greatly simplified, thus...

2.0807 Space Technology 7 Disturbance Reduction System - Precision Control Flight Validation

A Carmain, W Folkner, C Dunn (Jet Propulsion Laboratory); V Hruby, D Spence, T Roy, R McCormick, C Gasdaska, J Young, W Connolly (Busek Company), J O`Donnell, F Markley, P Maghami, O Hsu (NASA Goddard Space Flight Center)

The NASA New Millennium Program Space Technology 7 (ST7) project will validate technology for precision spacecraft control. The Disturbance Reduction System (DRS) will be part of the European Space Agency's LISA Pathfinder project. The DRS will control the position of the spacecraft relative to a reference to an accuracy of one nanometer over time scales of several thousand seconds. New colloid thrusters will operate over the range of 5

to 30 micro-Newtons with precision of 0.1 micro-Newton. The dynamic control system will cover eighteen degrees of freedom.

2.09 Space Mission Design: Technological Requirements and Orbit Selection

Session Organizer: Giovanni Palmerini, Universita` di Roma La Sapienza
Session Organizer: Trevor Williams, University of Cincinnati

2.0901 Relative Motion Model Including J2: Derivation and Application to INSAR

Giancarmine Fasano (University of Naples "Federico II"); Marco D`Errico (Second University of Naples)

An analytical model is presented, which allows a time-explicit representation of relative motion on the basis of orbital parameters' differences between satellites, in the case of a reference satellite moving on a circular and on a slightly eccentric orbit. Both derivations take into account secular J2 effects. Numerical analyses show that equations' errors are of the order of 0.1% of relative motion coordinates, and grow very slowly with time. Application of the model to interferometric missions proposed in literature allows to rediscover and better interpret results of numerical optimizations, and to point out possibilities deriving from relative trajectory evolution.

2.0902 Orbit Design and Optimization Based on Global Telecommunication Performance Metrics

Seungwon Lee, Charles H. Lee, Stuart Kerridge, Charles D. Edwards, and Kar-Ming Cheung (Jet Propulsion Laboratory)

The orbit selection of telecommunications orbiters is one of the critical design processes and should be guided by mission-specific performance metrics and constraints. In order to aid the orbit selection process, we have coupled the Telecom Orbit Analysis and Simulation Tool (TOAST) with genetic optimization algorithms. As a demonstration, we have applied the developed tool to find the optimal orbit for Mars orbiters with the constraint of traveling on a frozen orbit and the optimization goal of minimizing the telecommunication gap time. For the measurement of the gap time, several relevant metrics are constructed: 1) area-weighted average gap time...

2.0903 New Developments in the WAVE W-Band Mission

A. Jebril, M. Lucente, T. Rossi, M. Ruggieri (University of Rome-Tor Vergata), V. Dainelli (Oerlikon Contraves S.p.A), L. Zuliani (Italian Space Agency)

In this paper, an overview of the second phase (A2) of the WAVE (W-band Analysis and VErification) project is made. Two missions are introduced; Aero-WAVE using the M-55 Geophysica stratospheric aircraft for various experiments on the W-band channel propagation at 94 GHz and 82 GHz; and the nano-satellite LEO mission IKNOW (In-orbit Key-test and validatioN Of W-band) which will be used for a first uplink-downlink satellite channel characterization and in-orbit validation of W-band technology and space qualification processes. These applications are expected to help towards the realization of the GEO pre-operative payload defined in the phase-A of the project.

2.0904 Control Effort Evaluation for Low-Altitude Formation Flying

Marco Sabatini, Giovanni Palmerini (Universita` di Roma "La Sapienza")

LQR techniques based on Euler Hill dynamics have been repeatedly used for the analysis of formation flying. This paper introduces in the LQR control computation a modification of the Euler Hill model to include the effects of the air drag. Results for a leader follower and a circular projection cases show that cheaper control amount can be obtained with this approach. More correct estimates of the actuators' effort for low altitude formations can be therefore generated.

2.0905 Modelling of Periodic Relative Orbits Using Orbital Element Method

Shankar K Balaji, Adrian Tatnall (Astronautics Research Group,Southampton)

This paper will deal with the design of closed periodic orbits with the help of the Orbital Element developed by Balaji and Tatnall et al. The usefulness of this method is that it directly links the design parameters like the size and shape of the relative orbit with the

orbital properties of the spacecraft. Moreover there is no limitation on the eccentricity of the parent satellite unlike the CW method. A few test cases are considered and simulations are performed to demonstrate the validity of the method...

2.10 mm Wave and Quasi Optic Payload Optimization and Testing

Session Organizer: Roberto Lojacono, University of Rome
Session Organizer: Vittorio Dainelli, Oerlikon Contraves Spa

2.1001 Early Experiments with W-band Satellite Links

Giorgio Perrotta, Ahmed Jebril, Marina Ruggieri (University of Rome `Tor Vergata`)

The paper presents the study results for installing mini-payloads at W_band on a nanosatellite in LEO for experimentally assessing the propagation characteristics of the medium and the feasibility of performing low-availability, point-to-point, low to medium-high datarate links between satellites and fixed ground terminals. Two main W-band payloads and associated ground terminal configurations were considered: a modulated beacon transmitter and a regenerative repeater for conducting two-way links. Both can be accommodated on board a 3-axis stabilized nano-satellite in the 20 to 30 kg range, providing a power of 15-20 W to a MMW COTS_based payload.

2.1002 Innovative Technologies for the Developments of W-band Radars and Communication Payloads

Vittorio Dainelli (Oerlikon Contraves Spa); Ernesto Limiti, Marina Ruggieri (University of Roma Tor Vergata)

Scope of this work, in the frame of ASI (Italian Space Agency) program WAVE (W band Analysis and VErification), is the identification of innovative technologies to be used for design and development of on board W- band radars or telecommunication payloads. The development of multifunction low level W band MMICs has been investigated in order to reduce drastically dimensions, weight and costs. For which concern the power, an analysis of the performances of traditional or new “wide band- gap” MMICs has been done. At W-band, quasi optics technologies have been explored to minimize WR-10 waveguide losses to improve...

2.11 Advanced Technology Development for NASAs Mars Exploration Program

Session Organizer: Samad Hayati, Jet Propulsion Laboratory, Caltech

2.1101 Mars Technology Program Communications and Tracking Technologies for Mars Exploration

Dimitrios Antsos (Jet Propulsion Laboratory)

The future of the exploration of Mars will see an unprecedented increase in the volume of data generated by an increasingly capable host of spacecraft. To return these large volumes of data to Earth, communication links with data-rate capabilities in the multiple megabits-per-second will be required. The Mars Technology Program of the NASA managed by the Jet Propulsion Laboratory of the, has invested in a communications technology development program, described herein, which is developing technology components and products that will make these future high-capacity communications links from Mars viable.

2.1102 A UHF Proximity Micro-Transceiver for Mars Exploration

William Kuhn (Kansas State University); Norman Lay and Edwin Grigorian (Jet Propulsion Laboratory)

A UHF half-duplex micro-transceiver for future Mars exploration is described. The transceiver targets volume of less than 1cm 3, mass of 10 grams, and power consumption as low as 40mW receive and 50mW transmit (1Watt output optional), and it is compatible with a subset of Prox-1 protocols. In addition to its low mass/power features, temperature compensation and radiation tolerance allow operation outside of large, thermally controlled, shielded enclosures.

2.1103 Physical Layer Effects on MAC Layer Performance of IEEE 802.11 a and b WLAN on the Martian Surface

Anirudh Daga, Deva K. Borah, Gaylon R. Lovelace, Phillip De Leon (New Mexico State University)

The MAC layer performance of IEEE 802.11a and b WLAN standards on the Martian surface is studied. Three performance metrics are used: energy per successful bit, throughput per unit load and average delay. The effects of packet size, data rates, retry limits are studied and the use of RAKE receivers for 802.11b is considered. It is observed that the transmission parameters must be carefully selected in order to have acceptable performance levels. Overall, the performance of 802.11a is found to be better than the performance of 802.11b.

2.1104 Advances in Rover Technology for Space Exploration

Paul S. Schenker (Jet Propulsion Laboratory)

As NASA's two Mars Exploration Rovers (MER) continue their second year of operation at the red planet, the importance of surface mobility to space science is ever more apparent. In this paper we discuss some key problems in advancing performance of autonomous planetary rovers for future missions. Among the topics covered are the safe and accurate traverse of rough, science rich terrain, accurate localization and navigation of large terrain expanses, time-efficient and precise placement science instruments on targets of interest, on-board science data processing, and development of higher-level on-board "decision" skills. We also briefly discuss the development of a class...

2.1105 Object Modeling and Matching from Multi-view Ground Images for Automated Mars Rover Localization

Ron Li, Kaichang Di, Sanchit Agarwal, Jue Wang (The Ohio State University); Larry Matthies (Jet Propulsion Laboratory).)

This paper presents an innovative method for object modeling and matching from multi-view ground images for automated Mars rover localization. Rocks are first extracted from a selection of 3D ground points, and then are modeled using analytical surfaces. The extracted rocks of two rover stations are matched through a robust algorithm that matches the geometric configuration patterns of the rocks from the two stations. Experiments conducted using Navcam images acquired from the 2003 Mars Exploration Rover mission have demonstrated that the proposed method is capable of selecting cross-site tie points for two rover stations that are 26 m apart.

2.1106 Technologies for Exploring the Martian Subsurface

Suparna Mukherjee (Jet Propulsion Laboratory); Paul Bartlett (Honeybee Robotics); Brian Glass (ARC); Jose Guerrero (Swales Aerospace); Scott Stanley (Alliance Spacesystems Inc.)

The Mars Technology Program has invested in a number of development efforts with the collective goal of providing robust access to the martian subsurface for future landed missions. Currently funded technologies include a sampling system that will be able to penetrate hard rock to 20 m at flight-like power levels; shallow (0.5 m) regolith samplers appropriate for low-force platforms such as a rover-mounted robotic arm; a light-weight, low-force hard rock sampler that collects powdered sample; and an advanced automation task for permafrost drilling. A summary of capabilities and current status of each of these technologies is presented here.

2.1107 Development of Advanced Entry, Descent, and Landing Technologies for Future Mars Missions

Cheng-Chih Chu (Jet Propulsion Laboratory)

Future Mars missions may need the capability to land much closer to a desired target and/or advanced methods of detecting, avoiding, or tolerating landing hazards. As part of NASA Research Announcement, NRA 03-OSS-01, NASA solicited proposals for technology development needs of missions to be launched to Mars during or after the 2009 launch opportunity. Six technology areas were identified as of high priority including advanced entry, descent, and landing (EDL) technologies. In May 2004, 11 proposals were

awarded in the area of advanced EDL by NASA for further study and development. This paper presents an overview of these developing technologies.

2.1108 Low Temperature Thermal Cycle Survivability and Reliability Study for Brushless Motor Drive Electronics

Carissa D. Tudryn (Jet Propulsion Laboratory), Benjamin Blalock (University of Tennessee), Gary Burke, Yuan Chen, Scott Cozy, Reza Ghaffarian, Don Hunter, Michael Johnson, Elizabeth Kolawa, Mohammad Mojarradi, Don Schatzel, Andrew Shapiro (Jet Propulsion Laboratory)

This paper presents a survivability and reliability investigation for integrated actuator and brushless motor drive electronics packaging and components under an extreme low temperature and high thermal cycle environment. A universal brushless motor drive electronics assembly has been designed, built, and thermal cycle tested for use in Mars, moon, and asteroid type cold environments without the need for any active thermal control. The assembly uses electronic part types and chip-on-board electronic packaging technology that allow operation at temperatures down to –180°C. The thermal cycle capability of the assembly has been demonstrated to be in excess of 2010 cycles from -120C.

2.1109 Mars Miniature Science Instruments

Soon Sam Kim, Samad Hayati (Jet Propulsion Laboratory); David Lavery, Karen S. McBride (NASA)

Under NASA's Mars Technology Program, Mars Instrument Development Project (MIDP) has been developing miniature Mars In-situ instruments since 1998. Proposals for MIDP were selected through NASA Research Announcements (NRA) and managed by JPL for technical guidance and development. The objective of the MIDP is to bridge the gap between instrument R&D programs and flight hardware construction. For the purpose, MIDP selects and supports further development of promising instruments from breadboard level (TRL 3, 4) to a space qualifiable status (TRL 5, 6). So far, 37 instruments have been developed under MIDP, and four instruments have been selected by two Mars...

2.1110 Mars Technology Program Planetary Protection Technology Development

Ying Lin (Jet Propulsion Laboratory)

The objectives of the NASA Planetary Protection program are to preserve biological and organic conditions of solar-system bodies for future scientific exploration and to protect the Earth from potential hazardous extraterrestrial contamination. As the exploration of solar system continues, NASA remains committed to the implementation of planetary protection policy and regulations. To fulfill this commitment, the Mars Technology Program (MTP) has invested in a portfolio of seven tasks for developing necessary technologies to meet planetary protection requirements for the next decade missions. In this paper, we will give an overview of the tasks' objectives, current technical progress, and future directions...

2.1111 A Rapid Single Spore Enumeration Assay

Pun To Yung, Michael J. Kempf, Adrian Ponce (Jet Propulsion Laboratory)

The Rapid Single Spore Enumeration Assay (RapidSSEA) is being developed to aid planetary protection personnel in their efforts to validate bioburden reduction on spacecraft surfaces. RapidSSEA is based on imaging and counting individual bacterial spores in a microscope field-of-view, where the contrast is generated by a highly luminescent complex that forms when dipicolinic acid (DPA) is released from spores during germination and binds to terbium ions in the surrounding medium. Under pulsed UV excitation, the long-lived (τ 1 ms) DPA-triggered Tb luminescence is imaged by a lifetime-gated camera, essentially eliminating fluorescent interferents from the image.

2.1112 Telecommunications IT and Navigation for Future Mars Exploration Missions

E. Jay Wyatt, Todd. A. Ely, Matthew A. Klimesh (Jet Propulsion Laboratory); Christopher J. Krupiarz (The Johns Hopkins University Applied Physics Laboratory)

There are three primary drivers behind current investments in telecommunications information technology and navigation for Mars exploration. One is finding ways to maximize the volume of science data return since instrument data generation often

exceeds communication bandwidth. Another is developing technology to enable networked missions. The third driver is to enable precision landing so in-situ vehicles can be placed in more scientifically interesting regions. This paper describes current investments in these areas funded through the NASA Mars Technology Program. These are stereo image compression, next generation Mars relay protocols, and autonomous approach navigation using orbiter assets.

2.12 Space Station Science Experiments

Session Organizer: John Uri, NASA Johnson Space Center
Session Organizer: Vittorio Dainelli, Oerlikon Contraves Spa

2.13 Mars Entry, Descent and Landing

Session Organizer: Robert Braun, Georgia Institute of Technology
Session Organizer: Robert Manning, Jet Propulsion Laboratory, Caltech

2.1301 Mars Exploration Entry, Descent and Landing Challenges

Robert D. Braun (Georgia Institute of Technology); Robert M. Manning (Jet Propulsion Laboratory)

The United States has successfully landed five robotic systems on the surface of Mars, each with landed mass below 0.6 t. Current plans for human exploration of Mars call for the landing of 40-80 t surface elements within close proximity (10's of m) of pre-positioned robotic assets. This paper summarizes past successful entry, descent and landing systems and approaches being developed by the robotic Mars exploration program to increased landed performance (mass, accuracy and surface elevation). In addition, the entry, descent and landing sequence for a human exploration system will be reviewed, highlighting the technology and systems advances required.

2.1302 Status of Aerothermal Modeling for Current and Future Mars Exploration Missions

Michael Wright (NASA Ames), Karl Edquist, Brian Hollis (NASA Langley), Joe Olejniczak, Ethiraj Venkatapathy (NASA Ames)

The status of aerothermal analysis for Mars entry missions is reviewed. Two primary uncertainties in our ability to predict convective heating are turbulence and surface catalysis in a CO2 environment. Future missions, particularly crewed vehicles, will encounter additional heating from shock-layer radiation. Uncertainties inherent in the physical models employed to predict these phenomena are explored. Capabilities of ground test facilities to support aeroheating validation are also summarized. Engineering flight data from the Viking and Pathfinder missions are discussed. Examples are taken from past, present, and future Mars entry missions, including the twin Mars Exploration Rovers and the Mars Science Laboratory.

2.1303 Mars Deployable Decelerators Capability Roadmap Summary

Allen Witkowski (Pioneer Aerospace); Glen Brown (Vertigo)

Information presented in this paper was developed under NASA`s Human Planetary Landing Systems and Robotic Access to Planetary Surfaces Capability Roadmap teams and concerns technology development necessary to increase lander size from current limits. The current limit of experience for Mars landing is on the order of 1 metric ton (1000 kg) entry mass, with less than 20% of this devoted to science payload. Planned future landers require significant increases in science payload mass and eventual inclusion of humans.

2.1304 Performance Trades for Mars Pinpoint Landing

Aron A.Wolf, Jeff Tooley, Scott Ploen, Mark Ivanov, Behcet Acikmese, Konstantin Gromov (Jet Propulsion Laboratory)

Previous Mars landers have landed within tens to hundreds of km of a target. Principal sources of uncertainty are approach navigation, atmospheric modeling, and vehicle aerodynamics; lesser sources are map-tie error and wind drift. The 2009 Mars Science Laboratory mission will use entry guidance to improve this to 10 km. To achieve "pinpoint

landing" (within 100m), ways of addressing the remaining error sources must be found. This work defines a "reference system design" for pinpoint landing GNC, and assesses uncertainties and performance penalties associated with pinpoint landing using this design.

2.1305 Passive Imaging Based Multi-cue Hazard Detection for Spacecraft Safe Landing

Andres Huertas, Yang Cheng, Richard Madison (Jet Propulsion Laboratory)

Accurate assessment of potentially damaging ground hazards during the spacecraft EDL (Entry, Descent, and Landing) phase is crucial to insure a high probability of safe landing. We present a passive imaging based, multi-cue hazard detection and avoidance (HDA) system suitable for Martian and other lander missions. This is the first passively imaged HDA system that seamlessly integrates multiple algorithms crater detection, slope estimation, rock detection and texture analysis, and multi-cues crater morphology, rock distribution, to detect these hazards in real time.

2.1306 A Novel Tiered Sensor Fusion Approach for Terrain Characterization and Safe Landing Assessment

Navid Serrano, Max Bajracharya, Ayanna Howard (Georgia Tech), Homayoun Seraji (Jet Propulsion Laboratory)

This paper presents a sensor fusion methodology for terrain safety assessment. A combination of active and passive sensors, specifically, radar, lidar, and camera, operate in three tiers according to their inherent ranges of operation. Low-level terrain features (e.g. slope, roughness) and high-level terrain features (e.g. hills, craters) are integrated using principles of reasoning under uncertainty. Three methodologies are used to infer landing safety: Fuzzy Reasoning, Probabilistic Reasoning, and Evidential Reasoning. The safe landing predictions from the three fusion engines are consolidated in a subsequent decision fusion stage aimed at combining the strengths of each fusion methodology.

2.1307 Mars Science Laboratory Entry, Descent, and Landing System

Adam Steltzner, Devin Kipp, Allen Chen, Dan Burkhart, Carl Guernsey (Jet Propulsion Laboratory); Gavin Mendeck (JSC), Robert Mitcheltree (Jet Propulsion Laboratory), Richard Powell (LaRC), Tommaso Rivellini (Jet Propulsion Laboratory), Miguel San Martin (Jet Propulsion Laboratory), David Way (LaRC)

In 2010, the Mars Science Laboratory (MSL) mission will pioneer the next generation of robotic Entry, Descent, and Landing (EDL) systems by delivering the largest and most capable rover to date to the surface of Mars. Providing an EDL system capable of landing at high altitudes within ten kilometers of a targeted surface location will allow the science community to select the MSL landing site from thousands of scientifically interesting possibilities. This paper discusses the MSL EDL architecture, system, and subsystem design and discusses some of the challenges faced in delivering such an unprecedented rover payload to the Martian surface.

2.1308 Mars Science Laboratory Launch-Arrival Space Study: A Pork Chop Plot Analysis

Alicia Dwyer Cianciolo, Richard Powell (NASA Langley); Mary Kae Lockwood (John Hopkins University/Applied Physics Laboratory)

Launch-Arrival or "pork chop" plot analysis provides mission designers with valuable information and insight into a launch and arrival space for a mission. Nominal trajectories are simulated for each pair of launch and arrival dates and parameters of interest, such as maximum heat rate, are plotted in launch-arrival space. The plots help to quickly identify launch and arrival regions that are not available under current constraints and provide information for what technologies may need to be developed. This paper provides a discussion of the development, application and results of a pork chop plot analysis to the Mars Science Laboratory mission...

2.1309 Asymptotic Parachute Performance Sensitivity

David W. Way, Richard W. Powell (NASA-LaRC); Allen Chen, Adam D. Steltzner (Jet Propulsion Laboratory)

In 2010, the Mars Science Laboratory mission will pioneer the next generation of robotic Entry, Descent, and Landing systems by delivering the largest and most capable rover to

date to the surface of Mars. In addition to landing more mass than any other mission to Mars, Mars Science Laboratory will also provide scientists with unprecedented access to regions of Mars that have been previously unreachable. By providing an Entry, Descent, and Landing system capable of landing at altitudes as high as 2 km above the reference gravitational equipotential surface, or areoid, as defined by the Mars Orbiting Laser Altimeter program...

2.1310 Mars Science Laboratory Entry Descent and Landing System Verification and Validation Program

Robert Mitcheltree (Jet Propulsion Laboratory)

The Mars Science Laboratory (MSL) mission will land the next generation of robotic Entry, Descent, and Landing (EDL) systems on Mars in 2010. Relative to previous missions, the MSL EDL architecture will deliver a significantly larger mass to a higher altitude while maintaining a tighter delivery ellipse. MSL is pushing the limits of EDL technologies qualified previously by previous missions as well as introducing new elements into the architecture. Given the difficulties of conducting a meaningful end-to-end flight test on Earth, this combination introduces numerous challenges for the EDL Verification and Validation program.

2.14 Autonomous Vehicles

Session Organizer: Jack Langelaan, Department of Aeronautics and Astronautics

Session Organizer: Liam Pedersen, Carnegie Mellon University

2.1401 A Low Cost, High Performance Reconfigurable Computing Based Unmanned Aerial Vehicle

Grant Wigley, Mark Jasiunas (University of South Australia)

It12 has previously been stated that connectivity, computational processing power, and lack of resource integration are the three major limiting factors in developing the capabilities of small low-cost autonomous unmanned aerial vehicles (UAV). In an endeavor to address and overcome these limitations, we present details on a new UAV platform consisting of a commercially available airframe, off-the-shelf reconfigurable computing hardware, and a custom built operating system which does just that.

2.1402 Active Airborne Localisation and Exploration in Unknown Environments using Inertial SLAM

Mitch Bryson, Salah Sukkarieh (Australian Centre for Field Robotics)

We present an architecture for performing inertial-sensor based SLAM on an aerial vehicle, and analyse the observability properties of the inertial-SLAM algorithm and their relationship the manoeuvres of the platform. We demonstrate an on-line path planning scheme that intelligently plans the vehicle`s trajectory while exploring unknown terrain in order to maximise the quality of both the resulting SLAM map and localisation estimates. The path planner uses a combination of information measures and decision rules based on insight gained from the observability analysis in order to provide a practical and computationally feasible planner for real-time operations.

2.1403 A Robust Compositional Architecture for Autonomous Systems

Guillaume Brat, Ewen Denney, Kimberley Farrell, Dimitra Giannakopoulou, Ari Jónsson (Research Institute for Advanced Computer Science); Jeremy Frank (NASA Ames); Mark Boddy, Todd Carpenter (Adventium Enterprises); Tara Estlin, Mihail Pivtoraiko (Jet Propulsion Laboratory)

Space exploration applications can benefit greatly from autonomous systems. However, there is reluctance to utilizing autonomous systems. In part, this is due to general hesitation about new technologies, but a more tangible concern is the reliability and predictability of autonomous software. In this paper, we describe ongoing work aimed at increasing robustness and predictability of autonomous software, with the ultimate goal of building trust in such systems. The work combines state-of-the-art technologies and capabilities in autonomous systems with advanced validation and synthesis techniques. The focus of this paper is on the autonomous system architecture that has been defined, and on...

2.1404 A Lightweight Formation Control Methodology for a Swarm of Non-Holonomic Vehicles

Gabriel H. Elkaim, Robert J. Kelbley (UC Santa Cruz)

Multi-vehicle swarms offer the potential for increased performance and robustness in several key robotic and autonomous applications. This paper discusses a lightweight formation control methodology using conservative potential functions to ensure group cohesion, yet requiring very modest communication and control requirements for each individual node. Previous efforts have demonstrated distributed methods to navigate a vehicle swarm through a complex obstacle environment. It is shown that arbitrary formations can be held and morphed within the lightweight framework. Simulations of the lightweight framework applied to realistic nonholonomic tricycle vehicles highlight the swarm's ability to form arbitrary formations from random initial vehicle distributions and formation morphing capabilities, as well as navigate complex obstacle fields.

2.1405 Robust Coordination for Large Sets of Simple Rovers

Kagan Tumer, Adrian Agogino (NASA Ames)

The ability to coordinate sets of rovers to explore a dangerous, dynamic and unknown environments is critical to the long-term success of NASAs exploration missions. In this paper we present a distributed reinforcement learning method where each rover decomposes a system level reward into a rover-specific reward that properly assign credit to the rover`s actions. The results show that, in addition to being robust against noisy sensor inputs and noisy servo control, this method scales to large numbers of rovers and achieves up to 400% performance improvement over standard machine learning methods.

Track 3: Antenna Systems and Technologies

Track Organizer: Farzin Manshadi, Jet Propulsion Laboratory, Caltech
Track Organizer: Mark Thomson, Astro Aerospace

3.01 Phased Array Antennas

Session Organizer: Glenn Hopkins, Georgia Tech Research Institute

3.0101 Low-Voltage Ferroelectric Phase Shifters from L- to C-Band and their Applications

J. Stevenson Kenney, Yong Kyu Yoon, Minsik Ahn, and Mark G. Allen (Georgia Institute of Technology), Zhiyong Zhao, Xiaoyan Wang, and Andrew Hunt (nGimat Inc.), Dongsu Kim (Korean Electronics Technology Institute)

This paper describes the design, fabrication and test results of a family of integrated low-voltage ferroelectric phase shifters ranging in frequency of operation from 0.7 GHz to 6 GHz.

3.0102 Semiconductor Substrates in Phased Arrays - Integration Issues, Challenges and Laboratory Results

Janice C. Rock (U.S. Army Aviation and Missile Research)

This paper will discuss the ongoing research being conducted in the RF Technology Division of the Applied Sensors, Guidance, and Electronics Directorate, US Army Aviation and Missile Research, Development, and Engineering Center (AMRDEC) on the Redstone Arsenal in Huntsville, Alabama. The overall purpose of the research is to determine and overcome the technological barriers impinging upon enhancements to current phased array technology which is expected to include MEMS in addition to chip-level integration of multiple phased array components. An overview of phased array systems and components will be presented along with applications and insertion into potential military systems.

3.0103 Electromagnetic Study of Multilayer Media

Joel Booth, Stephanie E. Brown

This paper will discuss a basic electromagnetic analysis of multilayer material used in a radome application. The purpose of this work is to investigate a possible new configuration for a missile seeker. The discussion will be based on computer simulations with real world applications. This effort is being conducted in the RF Technology Division of the Applied Sensors, Guidance, and Electronics Directorate in conjunction with End Game Analysis, collocated at the US Army Aviation and Missile Command, Aviation and Missile Research, Development, and Engineering Center (AMRDEC) on the Redstone Arsenal in Huntsville, Alabama. The ground work for this effort...

3.0104 The UAVSAR Phased Array Aperture

Neil Chamberlain, Mark Zawadzki, Greg Sadowy, Eric Oakes, Kyle Brown, Richard Hodges (Jet Propulsion Laboratory)

The development of a microstrip patch antenna array for an L-band repeat-pass interferometric synthetic aperture radar (InSAR) is discussed in this paper. The antenna is designed to scan electronically in azimuth to compensate for aircraft yaw on repeated passes. The elements have a 10dB taper in elevation to reduce multipath interference from the aircraft wing. The taper is implemented in the interconnect circuits as opposed to using attenuators in the T/R modules. Predicted and measured electromagnetic performance is presented, along with details of material choices and fabrication techniques.

3.02 Ground Antenna Technologies and Systems

Session Organizer: Farzin Manshadi, Jet Propulsion Laboratory, Caltech
Session Organizer: Vahraz Jamnejad, Jet Propulsion Laboratory, Caltech

3.0201 Thermal Considerations for Hydroformed Reflectors

William A. Imbriale, Eric Gama (Jet Propulsion Laboratory); Kenneth S. Smith (Alliance Spacesystems, Inc.);Roger Shultz (Schultz Associates)

One antenna design proposed for the next generation Deep Space Network (DSN) array and the Square Kilometer Array (SKA) is a hydroformed symmetrically shaped dual reflector system. One concern about the performance is the surface deformation caused by thermal gradients. The first DSN 6-meter dish was unpainted aluminum and measurements of surface rms under mid-day sun showed an rms exceeding the specification. After application of the triangle no. 6 diffusive white paint, the rms met specification. This paper discussed the thermal design and performance of the 6-meter hydroformed reflector as well as projecting the performance of the SKA 12-meter antenna.

3.0202 Lower-Cost Architectures for Large Arrays of Small Antennas

Dayton Jones (Jet Propulsion Laboratory)

Future plans for NASA`s Deep Space Network (DSN) call for the construction of arrays of small antennas to replace the existing network of large single antennas. As currently designed, the DSN arrays will consist of approximately four hundred 12-m diameter antennas at each of three longitudes, operating at X and Ka bands (8 and 32 GHz). A possible near-term option is the construction of large arrays operating at X-band only. Such an array could be built less expensively and would be able to support the majority of space missions planned for the next 20 years.

3.0203 Mathematical Gain Models of Large-aperture Earth Station Antennas for Space Research Service

Vahraz Jamnejad, Ted Peng (Jet Propulsion Laboratory)

Compatibility studies for Space Research Service (SRS) earth stations and high-density fixed systems are being conducted in 31.8-32.3 GHz and 37-38 GHz bands. A key element in determining the level of interference at SRS earth stations is the antenna gain pattern used in calculations. Here a new gain model is proposed for peak and average envelopes of the class of large aperture antennas currently in use at SRS earth stations, for use in International Telecommunication Union recommendations. This model includes surface tolerance and aperture efficiency effects on main-beam and side-lobes. Integrated average gain is used as a validity check.

3.03 Space Antennas Technologies and Systems

Session Organizer: Mark Thomson, Astro Aerospace
Session Organizer: Yahya Rahmat-Samii, UCLA

3.0301 Combined UHF/X-Band Proximity Link Antenna for Future Mars Telecommunications Orbiters

Raymond L. Lovestead (formerly with Ball Aerospace & Technologies Corp.); Anthony J. Jensen (Ball Aerospace & Technologies Corp.)

Combining antenna apertures into a single unit reduces weight, volume, complexity, and cost and frees up valuable space on a satellite for other critical sensors and equipment storage. Ball Aerospace provides such a solution through its Vitreous® antenna technology which utilizes antennas that are electrically transparent to each other and combines them within a single volume. This paper presents a 9-element Vitreous® UHF array with an embedded high gain X-band array, providing 15 dBic of gain at UHF (390 to 450 MHz), 24 dBic at 7.17 GHz and 27 dBic at 8.42 GHz in a 1.4x1.4x0.06m volume.

3.0302 An S Band Antenna System Used for Communication on Earth Observation Microsatellite

L. Hadj Abderrahmane (CNTS, Algeria); M. Benyettou (USTO, Algeria); M. N. Sweeting (SSTL UK)

This paper describes an S band antenna system used on microsatellite constituted by three different RF antennas: S-Band Patch antenna (for command uplink), S-Band Monopole antenna (for telemetry downlink), and S-Band Quadrafilar Helix antenna (for payload downlink).

3.04 Microwave Remote Sensing Technologies and Systems

Session Organizer: Gregory Sadowy, Jet Propulsion Laboratory, Caltech
Session Organizer: James Carswell, Remote Sensing Solutions

3.0401 Initial results of the GeoSTAR Prototype (Geosynchronous Synthetic Thinned Array Radiometer)

A. B. Tanner, S. T. Brown, S. J. Dinardo, T. M. Gaier, P. P. Kangaslahti, B. H. Lambrigtsen, W. J. Wilson (Jet Propulsion Laboratory); J. R. Piepmeier (Goddard Space Flight Center); C. S. Ruf, S. M. Gross, B. H. Lim, S. Musko, S. Rogacki (University of Michigan)

A prototype of the Geostationary Synthetic Thinned Array Radiometer (GeoSTAR) will be presented. GeoSTAR is a concept for a Y-array of correlation interferometers operating in bands from 50 GHz to 180 GHz. This paper presents preliminary data from a small (24-element) 50-55 GHz prototype system which has been built under NASA's Instrument Incubator Program to demon-strate the basic technology and calibration techniques needed for the larger (300 element) spaceborne system. Images are synthesized by Fourier Transform of interferometric data. An outline of the data processing will be presented, along with the first images from this system.

3.0402 High Power Electronic Scanning Millimeter-Wave Radar System Design

Stephen M. Sekelsky, James Carswell (Remote Sensing Solutions, Inc.)

Remote Sensing Solutions, Inc has received NASA funding to design a prototype millimeter-wave radar system that will lead to future generations of large aperture space-borne electronic scanning radars. A scanning millimeter-wave radar is critical tool for improving the remote sensing of the Earth and other bodies in our solar system. Low power solid-state scanning millimeter-wave radar systems cannot provide the necessary sensitivity to detect low reflectivity cloud particles, especially at longer ranges from space.

3.0403 ImagingWind and Rain Airborne Profiler for Remote Sensing of the Ocean and the Atmospheric Boundary Layer

Daniel Esteban Fernandez, Paul S Chang (NOAA/NESDIS); James R. Carswell (Remote Sensing Solutions); Robert F. Contreras, Stephen J. Frasier (University of Massachusetts)

IWRAP, the Imaging Wind and Rain Airborne Profiler, is the first high-resolution dual-band airborne Doppler radar designed to study the inner core of Tropical Cyclones (TCs). IWRAP is currently operated from a National Oceanic and Atmospheric Administration (NOAA) WP-3D aircraft during missions through TCs and severe ocean storms. The system is designed to provide high-resolution, dual-polarized, multi-beam C- and Ku-band reflectivity and Doppler velocity profiles of the atmospheric boundary layer within the inner core precipitation bands of TCs and to study the effects precipitation has on ocean wind scatterometry as it applies to TCs. This dual-wavelength system also provides for the use of differential attenuation techniques to derive the rainfall rate...

3.0404 A Highly Capable Arbitrary Waveform Generator for Next Generation Radar Systems

Chung-Lun Chuang, Scott Hensley, Kevin Wheeler (Jet Propulsion Laboratory)

An Arbitrary Waveform Generator (AWG) is being developed to provide enhanced capability for radar applications. The basic architecture of this unit employs a Field Programmable Gate Array (FPGA) and a high speed and high precision Digital to Analog Converter (DAC) for direct digital synthesis. This AWG will be capable of up to 500MHz bandwidth with ability for frequency notching while maintaining high phase fidelity. These capabilities along with lower power consumption compared with previous spaceborne waveform generators will enable future radars to return higher precision data, to be reduced in complexity, and to operate without interfering with dedicated bandwidths.

3.05 Antenna Systems: Novel Modeling and Optimization Techniques

Session Organizer: Ahmad Hoorfar, Villanova University
Session Organizer: Vahraz Jamnejad, Jet Propulsion Laboratory, Caltech

3.0501 Numerical Analysis of Large Reflector System used as a Ground Station Antenna

Nader Farahat(Polytechnic University of Puerto Rico), Raj Mittra (The Pennsylvania State University), and Jesus Sanchez(Polytechnic University of Puerto Rico)

In this paper, we investigate a large dual-reflector (Cassegrain) antenna system, typically used as a ground station antenna in the space communication link. The large electrical dimension of the reflector makes it impractical to analyze it via direct numerical simulation using the available computer codes. However, the problem becomes manageable if we first use the Body of Revolution version of the FDTD code we have developed to model the axially-symmetric part of the structure viz. the feed, the reflector and the subreflector, and then modify the obtained aperture field by nulling out the fields in shadow regions.

3.0502 Sum and Difference Beam-Pattern Synthesis with Side-Lobe Control

Nivia Colón-Díaz, Thomas E. Morton (Air Force Research Laboratory); Krishna M. Pasala (University of Dayton)

This paper ,2 considers the synthesis of sum and difference beam patterns for a planar array of antenna elements to be used as a tracking antenna. The patterns are synthesized using an optimization such that the directivity of the sum pattern is maximized subject to prescribed sum and difference pattern side-lobe levels. A significant result is that the sum and difference patterns are synthesized with the same set of complex weights. Beam pattern results are presented for a given prescribed side-lobe level with and without beam scanning. In addition, it is of interest to maximize the slope of the difference...

3.06 Array Beamforming Technologies: Analog, Digital, and Optical

Session Organizer: Hans Steyskal, Air Force Research Lab. /SNHA
Session Organizer: Jeffrey Herd, MIT Lincoln Laboratory

3.0601 Rotman Lens Development at the Army Research Lab

Steven Weiss, Robert Dahlstrom (The Army Research Lab)

An electronic scanning antenna (ESA) that uses a beamformer for scanning the beam has the advantage of being able to form multiple beams for multimode, shared-aperture applications. This scanning approach is achieved at a reduced parts count for the antenna subassembly and therefore at a lower cost than approaches utilizing phase-shifting elements for controlling the beam. This paper discusses our efforts to realize such a beamformer using Rotman lens geometry and details some of the technologies we investigated as well as some engineering tradeoffs encountered.

3.0602 Antenna Design and Beamforming for a Conformal Antenna Array Demonstrator

P. Knott (Research Institute for High Frequency Physics, and Radar Techniques)

The present paper gives an overview over a radar demonstrator currently under development and the design of the system's conformal antenna array front-end. Important system parameters and overall performance of the planned system are described and experimental results for reflection coefficients, mutual coupling and embedded antenna element far field patterns will be included as well as simulated pattern synthesis results for different operational modes. A circularly polarized antenna sub-array suitable for integration in double curved apertures combining multiple cavity-backed patch antennas on a circular substrate has been developed and preliminary results are presented.

3.0603 Initial Demonstration of an X-Band Digital Beamforming (DBF) Receive Array

Daniel N. Spendley, Lt Joseph D. Rosal, and David D. Curtis (Air Force Research Laboratory); William H. Weedon and John Burroughs (Applied Radar, Inc.)

This paper presents the architecture and initial measured performance of an X-Band Digital Beamforming Receive Array. This processor was designed to steer four independent

simultaneous beams over X-band with 32 independent channels, an instantaneous bandwidth of 15 MHz, and a spur-free dynamic range 65 dB, while achieving a decrease in size and weight when compared to past DBF systems. Although the processor is designed to use 32 channels, the initial recorded measurements used only 8 to 12 elements. Nevertheless, these initial patterns demonstrate behavior similar to their predictions and give promise to the technology's applicability towards smaller airborne platforms.

3.0604 Analysis of Signal to Noise Ratio in Photonic Beamformers

N. M. Froberg, E. I. Ackerman and C. H. Cox III (Photonic Systems, Inc.)

The goal of this paper is to characterize the impact of photonic beamformers on the amplitude and the signal-to-noise ratio (SNR) of RF signals received by a phased array antenna. To this end, the two-port definitions of RF gain and noise figure are generalized to include multiple-port combining devices such as beamformers. These metrics are then applied to simple photonic and hybrid RF/photonic beamformer architectures. As expected, reducing optical loss in the beamformer is essential for achieving high RF gain and SNR at the beamformer output, and several low-loss photonic beamformer architectures are identified.

3.07 Applications of Non-linear Dynamics

Session Organizer: Robert Kerr, Georgia Tech Research Institute
Session Organizer: Ted Heath, GTRI - SEAL

3.0701 Robust Tracking Control of Attitude Satellite with Using New SMC and EKF for Large Maneuvers

Mehrdad Jafarboland, Nasser Sadati, Hamidreza Momeni

Control, of a class of uncertain nonlinear systems which estimates unavailable state variables is considered. A new approach for robust tracking control problem of satellite for large rotational maneuvers is presented in this paper. The features of this approach include –a strong algorithm to estimate attitude, based on discrete extended kalman filter combined with a continuous extended kalman filter and attitude nonlinear model –a robust controller based on sliding-mode with perturbation estimation. The estimation result of interval kalman filtering is a sequence of interval estimates that encompasses all possible optimal attitude estimates, which the interval system may generate.

3.0702 Disturbance and Parameter Estimation Algorithms for Attitude Control Model of the Satellite Maneuvers

Mehrdad Jafarboland, Hamidreza Momeni

The design, of robust tracking control for a non-linear MIMO system having modeling uncertainty and unknown disturbance is one of the most complicated control problems. In this paper two new algorithms for tracking control are presented which guarantee the satellite attitude during small maneuvers having desired attitude angle. The amplitude of the control signal and consumed energy is less than the related value concerning the sliding mode with perturbation estimation, which are usually applied for large maneuvers.

3.0703 Nonlinear Oscillator Array Antenna Development at GTRI

Ted H. Heath, Robert R. Kerr, Glenn D. Hopkins (GTRI)

This paper reviews the Georgia Tech Research Institute's (GTRI) contributions to the field of nonlinear oscillator antennas. Over the last five years, GTRI, in collaboration with SPAWAR Systems Center in San Diego, has advanced the state of the art in the analysis, capability and design of coupled oscillator arrays. A theoretical framework describing the dynamics of coupled oscillators and its relevance to beam steering, beam shaping, monopulse and null steering is presented. Descriptions of 1- and 2-dimensional array designs are provided, including critical design issues encountered during their development. Performance assessments via range chamber testing and on-board diagnostic measurements are...

3.0704 Coupled Oscillator Based Agile Beam Transmitters and Receivers: A Review of Work at JPL

Ronald J. Pogorzelski (Jet Propulsion Laboratory)

This review summarizes work conducted at JPL during the past decade concerning the use of coupled oscillator arrays to provide properly phased signals both for excitation of the elements of agile beam transmit antennas and for downconversion of signals received on such array elements in receive mode. Considerable theoretical work is described that has resulted in a detailed understanding of the design and behavior of such arrays and several experiments are also described attesting to the practical implementation of the concept and pointing the way toward future fully integrated agile beam transmit/receive systems based on this technology.

3.0705 Adaptive Interference Mitigation with a Coupled Nonlinear Oscillator Array Beamformer

Takeshi Ikuma, A. A. (Louis) Beex (Virginia Tech), James R. Zeidler (University of California, San Diego); Brian K. Meadows (SPAWAR Systems Center)

We present a novel implementation of an adaptive generalized sidelobe canceller beamformer, using a coupled nonlinear oscillator array in conjunction with an antenna array. This beamformer is applied in the context where there is contamination due to similar transmissions. We use a least mean square like algorithm to compute weight updates for rejecting interfering signals while maintaining the desired beam. The beamformer weight update is performed indirectly, via adjustment of the coupling parameters of the coupled nonlinear oscillator array. Computer simulation of the proposed approach for a narrowband communication system shows successful adaptation and rejection of the interfering signals.

3.0706 Improved Mutual Injection Locking Range for VCOs in a Coupled Oscillator System

Chris Tompkins, Venkatesh Seetharam, L. Wilson Pearson (Clemson University)

Coupled oscillator arrays (COAs) have been introduced as a simple, low cost method to achieve spatial power combining with the flexibility to generate the phase shifts necessary for beam steering applications. One difficulty in fabricating large scale COAs is the need for tight fabrication tolerances, but with oscillator cells designed to manifest wide locking range the tolerance is maximized. This paper describes the theory of coupled oscillator arrays and identifies the relationships between injection locking range, cell-to-cell frequency deviation, and phase error. Measured results for small fabricated arrays are presented, with as much as 6% locking range.

Track 4: Communication & Navigation Systems & Technologies

Track Organizer: Phil Dafesh, The Aerospace Corporation
Track Organizer: Shirley Tseng, Infinite Global Infrastructures

4.01 Responsive Space Transformation

Session Organizer: Doug Holker, The Aerospace Corporation
Session Organizer: Edward Jones, SMC/TDZ

4.0101 Constella: Quick Configuration Platform for Rapid Response Missions

Martinus (Max) Meerman, Martin Sweeting (Surrey Satellite Technology Limited)

Constella is a novel very quick response satellite platform. It can be pre-manufactured to a large extent, and it allows last-minute configuration options for both the payload and platform. The total mission development time can be down to weeks or even days. Constella can be tailored with interchangeable attitude sensors, propulsion units, communications equipment, payloads and more, just before launch, even right at the launch site if required. The platform is compatible with any inclination or hour angle. The design of the platform requires very little assembly space and time, further increasing versatility and lowering cost.

4.0102 Preliminary On-orbit Maneuver Analysis for Responsive Space Applications

1Lt Edward E. Jones (USAF AFSPC); Alisa M. Hawkins (The Aerospace Corporation)

One solution to meet the recent interest within the US government for more responsive space systems is the ability for increased on-orbit manuever. Spacecraft maneuvers can provide much of the same utility as responsive launch for less than 100 m/s of velocity change, without launching a new rocket and spacecraft. Preliminary results show that small burns can hasten or delay a pass, work to change the orbital plane to something more suitable for a given theater, or change the time over target and geometry within the theater.

4.02 Evolving Space Communication Architectures

Session Organizer: Robert Cesarone, Jet Propulsion Laboratory, Caltech

4.0201 RF Technologies for Advancing Space Communication Infrastructure

Irene Bibyk, Robert Romanofsky, Ed Wintucky (NASA Glenn Research Center)

This paper will address key technologies under development at the NASA Glenn Research Center designed to impact the exploration communications architecture. Specifically, we will describe deployable antennas, a new type of phased array antenna and novel power amplifiers. These technologies can play a role in CEV operations and possibly lunar ground and relay satellite scenarios. Key technical challenges for a large deployable antenna include maintaining RMS surface accuracy consistent with Ka-band operation and developing reflector rigidization techniques. Moreover, the high frequencies and large apertures manifest a problem for microwave engineers that are familiar to optical communications specialists: pointing.

4.0202 Applications and Operation Concepts of Large Transmit Phased Array of Parabolic Reflectors

Farid Amoozegar (Jet Propulsion Laboratory)

The primary motive, for large transmit array of parabolic reflectors, also known as Uplink Array, was to explore alternate methods in order to replace the large 70m antennas of Deep Space Network (DSN) such that the core capability for emergency support to a troubled spacecraft in deep space is preserved. Given that the Uplink Array is a new technology, the focus has always been on its feasibility and phase calibration techniques, which by itself is quite a challenge. It would be interesting to examine, however, what else could be accomplished by the Uplink Array capability other than the emergency...

4.0203 Exo-Atmospheric Telescopes for Deep Space Optical Communications

William J. Hurd, Bruce E. MacNeal, Gerardo.G.Ortiz (Jet Propulsion Laboratory); Edward S. Cheng (Conceptual Analytics); Rud V. Moe, Jon Z. Walker (NASA Goddard Space Flight Center); Debora A.

Fairbrother (NASA Wallops Flight Facility); Michael L. Dennis (JHU Applied Physics Laboratory); Bente Eegholm (Swales Aerospace); K. J. Kasunic (Ball Aerospace & Technologies)

For deep space optical communications, exo-atmospheric telescopes have significant advantages over surface-mounted telescopes, due to eliminating atmospheric effects including weather. This study identifies the two most promising platforms to be satellites and high-altitude powered airships. System configurations were compared that would have data rate capability comparable to a 6-m to 10-m diameter ground-mounted telescope, 100 percent line-of-sight coverage to a deep space spacecraft in the ecliptic, and at least 80 percent coverage in the event of failure of one Earth terminal. Based upon technical feasibility and readiness, life-cycle cost, performance and risk, a satellite platform is recommended.

4.0204 End-to-End Information System Concept for the Mars Telecommunications Orbiter

Julian C. Breidenthal, Charles D. Edwards, Edward Greenberg, Greg J. Kazz, Gary K. Noreen (Jet Propulsion Laboratory)

The Mars Telecommunications Orbiter (MTO) was intended to provide high-performance deep space relay links to the vicinity of Mars, to demonstrate interplanetary laser communications, to demonstrate autonomous navigation, and to carry out its own science investigations. We describe here the end-to-end information system (EEIS) concept for provision of six major types of services by the MTO. We also discuss the key design drivers and strategies employed in the EEIS design, and possible extensions to accommodate scenarios beyond the original MTO mission requirements.

4.03 Communication Protocols and Services for Space Networks

Session Organizer: Humayun Arif, Cisco Systems, Inc.
Session Organizer: Loren Clare, Jet Propulsion Laboratory, CalTech

4.0301 Ka-Band Link Optimization with Rate Adaptation

Jay Gao (Jet Propulsion Laboratory); Jun Sun, Eytan Modiano (MIT)

On-going development of Ka-band capability for the Deep Space Networks (DSN) will radically increase the bandwidth available for future robotic and human exploration of Mars and beyond. While Ka-band links operates at much higher data rate, it is susceptible to fluctuating weather conditions. To improve the throughput-availability trade-off, data rate adaptation based on real-time observation of the channel condition is necessary. We model the ka-band channel using a Markov process to capture the temporal correlation in weather conditions and develop channel prediction and rate adaptation algorithms to optimize the data rate in real time.

4.0302 An Advanced Orbiting Systems Approach to Quality of Service in Space-Based Intelligent Communication Networks

Andrew P. Riha (Iowa State University), Clayton Okino (Jet Propulsion Laboratory)

As humans and robotic technologies are deployed in future constellation systems, differing traffic services will arise, e.g. realtime and non-realtime. In order to provide a quality of service framework that would allow humans and robotic technologies to interoperate over a wide range of interactions, a method of classifying data as realtime or non-realtime is needed. We present an approach that leverages the CCSDS Advanced Orbiting Systems (AOS) data link protocol. Specifically, we redefine the AOS Transfer Frame Replay Flag in order to provide an automated store-and-forward approach on a per service basis for use in the next-generation Interplanetary Internet.

4.0303 A Non-Broadcast Address Resolution Protocol for SpaceWire Networks

Sandra G. Dykes, Buddy Walls, Mark A. Johnson, Kristian Persson (Southwest Research Institute)

SpaceWire is a switched network designed for space environments. To support the Internet Protocol (IP) and other high level network protocols, SpaceWire requires a method for mapping the physical interface addresses to global network protocol addresses. Standard address resolution protocol (ARP) cannot be used because SpaceWire does not have a

broadcast mechanism. This paper describes a non-broadcast SpaceWire ARP (SW-ARP) that supports IPv4, IPv6, and CCSDS SCPS-NP. SW-ARP can be implemented in software drivers and requires no changes to the interface hardware, SpaceWire routers, or the SpaceWire standard specification.

4.0304 The NASA Space Communications Testbed (SCT)

Jack Rieser, Kirk Berry (Comsat Laboratories, a Division of ViaSat), Loren Clare (Jet Propulsion Laboratory), Richard Slywczak (Glenn Research Center)

A robust space communications network will play a key role in the planning and execution of safe and successful manned and robotic missions to the Moon, Mars and beyond. As future space missions become increasingly complex, it is essential that NASA develop a low cost method for validating, optimizing and verifying communications architectures, technologies and operational procedures. The Space Communications Testbed is being developed by Comsat Laboratories, GRC, JPL, GFSC, and LaRC. The SCT will be geographically distributed and seamlessly integrated between Comsat Laboratories and the various NASA Centers with each providing support in their relevant areas of expertise.

4.0305 Adaptation, Modeling, and Analysis of PIM DM in a LEO Satellite Network Environment

Victor P. Hubenko, Jr. Richard A. Raines, Michael A. Temple, Robert F. Mills (Air Force Institute of Technology); Mark D. Saeger (Air Force Research Laboratory)

Multicast communication protocols continue to evolve as more applications take advantage of the efficiencies afforded by the ability of a single source to reliably send data to many users and vice versa. This article continues that evolution and provides analysis on three multicasting protocols (PIM-DM, DVMRP, and ODMRP), adapted to a Low Earth Orbit Satellite Network. We provide a simplified overview of multicasting and the three protocols highlighted. We then discuss the implementation details required to adapt the protocols for a satellite network environment, and deviations from the protocols that we found necessary.

4.0306 Energy Efficient Transmission Scheduling over Mars Proximity Links

Alessandro Tarello (Politecnico di Torino); Jay L. GAO, (Jet Propulsion Laboratory); Eytan H. Modiano, (MIT)

We consider the scheduling of transmissions from an energy limited Mars lander to a Mars orbiter. The channel quality of the Mars proximity links is time-varying due to orbital dynamics, multi-path effects and the antenna positioning on the lander. Since the channel state determines the throughput obtained per unit of energy transmitted, it is desirable to select when, and at what data rate, to transmit based on channel conditions. In this paper we consider the dual problem of maximizing the throughput given a limited amount of energy to be used for transmission; and minimizing the energy consumption given deadline constraints.

4.0307 A Split Implementation of the Dynamic Source Routing Protocol for Lunar/Planetary Surface Communications

Jerry Toung (Advanced Management Technology, Inc.); Raymond Gilstrap, Kenneth Freeman (NASA Ames)

Members of future NASA planetary surface exploration teams will need to communicate interactively with each other. However, these surface elements are mobile and may lose communication due to distance or obstructions. This problem can be addressed with a mobile ad hoc network routing protocol, which allows nodes unable to communicate directly to remain in contact by relaying data through one or more intermediate nodes. We have implemented such a protocol, Dynamic Source Routing (DSR). We have tested DSR in the field and found the protocol promising for enhancing surface communications.

4.0308 A Link-State Routing Approach for Formation Flying Spacecraft

Pitiporn Pakdeepinit, Tapanan Yeophantong, Thanachai Thumthawatworn, Pratit Santiprabhob (Assumption University)

One of the many challenges facing the system formation flying spacecraft is the communication among spacecraft within the same cluster, i.e. a set of spacecraft flying

together in some specific formation, as well as with those of other related clusters. In this paper, a routing framework is proposed to allows spacecraft to share connection quality information which can be considered as decision parameters including data rate, propagation delay, reception signal strength, and bit error rate. The participating spacecraft use this information to build and maintain connection topology and routing tables for efficient communication both within a cluster and between clusters.

4.04 Transformational Communications Architectures and Technologies

Session Organizer: Frederic Agardy, The Aerospace Corporation

4.0401 Global Assessor: Transformational Tools for Transformational Missions

Dan Walkovitz (Mainstay Software Corporation); Richard Baumeister (Boeing Phantom Works)

This paper contains a description of the prototype Global Assessor tool being developed by Boeing Phantom Works and Mainstay Software Corporation. The purpose of the tool is to support evaluation of Global Tracking Relay and Control Concept implementations being developed by the Phantom Works Joint Mission Study. The Joint Mission Study is a Phantom Works Advanced Platform Systems project that began in 2001 to evaluate how to apply high-leverage Department of Defense intelligence collection capabilities and blue force tracking technologies in support of evolving to a global Air Traffic Management capability for civil (FAA) and military applications. The Global Assessor...

4.0402 TSAT Advanced Network Services and Routing Architecture

Ferit Yegenoglu, Dan Voce, and Dilip Gokhale (Lockheed Martin)

In this paper we provide an overview of the Transformational Communications Satellite (TSAT) baseline routing architecture and illustrate how policy-based route filtering can be used to support special connectivity scenarios such as Virtual Private Networks (VPNs), intradomain connectivity in the presence of backdoor links, and split Autonomous System (split-AS) interconnection.

4.0403 QoS Architecture for Session Oriented GIG Applications

Anshul Kantawala, Dan Voce, Dilip Gokhale (Lockheed Martin)

In this paper, we survey existing QoS architectures for the Internet such as IntServ, DiffServ, Bandwidth Broker etc. and present a detailed survey analysis comparing the different QoS alternatives in terms of their applicability to the GIG. For each architecture, we evaluate its suitability for providing QoS guarantees in each of the three main network component types of the GIG: MANETs, Satellite networks and GIG-Bandwidth Expansion (GIG-BE); and how they would interact with each other to provide end-to-end QoS. We also briefly present hybrid QoS architectures that may be suited to provide end-to-end QoS in the GIG.

4.05 End to End Communications Architectures for Moon and Mars Exploration

Session Organizer: Stephen Braham, PolyLAB, TIME Centre

4.06 Navigation and Communication Systems for Exploration

Session Organizer: Patrick Stadter, JHU/Applied Physics Laboratory
Session Organizer: Robert Bokulic, Johns Hopkins University Applied Physics Laborator

4.0601 Evolvable Navigation and Communication Infrastructure for Lunar Exploration

P. A. Stadter, P. J. Sharer, J. J. Guzman, C. S. Engelbrecht, D. A. Eng, E. J. Finnegan, D. B. Bussey, P. D. Spudis, C. L. B. Reed (The Johns Hopkins University Applied Physics Laboratory); S. Nozette (NASA/HQ)

The NASA Exploration Initiative provides a defining vision for the U.S. space program and an implementation of U.S. policy that will include a series of human and robotic missions to the Moon with a goal to thereby enabling ultimate exploration of Mars and other destinations. These missions can be aided and enabled by a navigation and

communication infrastructure that can evolve in capability to support lunar operations and data collection. This paper describes a system concept for evolving a lunar navigation/communication infrastructure (LNCI). The described approach uses small spacecraft that are capable of launch as auxiliary payloads.

4.07 Space Exploration Communication and Navigation Status and Panel

Session Organizer: Ronald Miller, NASA

4.08 Optical Communication in Space Systems

Session Organizer: Stephen Townes, Jet Propulsion Laboratory, Caltech

4.0801 Application of Adaptive Optics to a Moon-to-Earth Optical Data Link

Gregory Konesky (SGK Nanostructures, Inc.)

The anticipated return to the Moon will require high bandwidth communications support for both manned and unmanned operations. An optical data link consisting of a 1 Watt laser on the Moon, transmitted through a 1 meter aperture and received on the Earth by a 1 meter aperture (at 830 nm) will produce a net positive link margin. Adaptive optics can be used to negate atmospheric effects, within limits. Alternately, optical reception can be affected in Earth orbit. The tradeoffs between these two approaches are considered in terms of implementation complexity and link availability.

4.0802 Near-Sun Free-Space Optical Communications from Space

A. Biswas (Jet Propulsion Laboratory); F. I. Khatri and D. Boroson (MIT Lincoln Laboratory)

Free-space optical communications offers expanded data return capacity, from probes distributed throughout the solar system and beyond. Space-borne and Earth-based optical transceivers used for communicating optically, will periodically encounter near-Sun pointing. This will result in an increase in the scattered background light, contributing to degraded link performance. The duration of near-Sun pointing link operations relative to the location of space-probes, is discussed in this paper. The impact of near-Sun pointing on link performance for a direct detection photon-counting communications system is analyzed for both ground- and space-based Earth receivers.

4.0803 The Effect of Synchronization Errors on the Performance of Telescope Arrays for Optical Deep Space Communications

Ali Asghar Eftekhar, Ali Javad Hashmi, Ali Adibi (Georgia Institute of Technology); Farid Amoozegar(Jet Propulsion Laboratory)

Evolving optical deep space communication network requires incremental growth in the total aperture. The cost of a large aperture telescope grows exponentially as a function of its diameter, therefore telescope array architecture could provide a cost effective scalable growth for an evolving optical deep space network. In this paper, the effect of synchronization on the performance of the telescope arrays is analyzed. It is shown that the degradation in combined signal due to synchronization error can be reduced to a small value so that it places only a minor limitation on the number of the telescopes in a telescope array.

4.09 Innovative Techniques in Deep Space Communications

Session Organizer: Christopher DeBoy, JHU/APL

4.0901 Flexible Coherent Digital Transceiver for Low Power Space Missions

Christopher B. Haskins, Wesley P. Millard, J. Robert Jensen (The Johns Hopkins University Applied Physics Laboratory)

A flexible coherent digital transceiver architecture has been developed by the APL in order to enable mission specific performance tailoring while maintaining modularity and minimizing program-incurred cost and risk. Using this new architecture, a low power, coherent, X-band digital transceiver has been made that meets the requirements for two-way Doppler tracking. The new transceiver contributes less than 0.01 mm/s to the Doppler

velocity error measured over a 60-second interval in coherent mode. Secondary power consumption is 2.8 W in the uplink-only mode of operation including the reference oscillator.

4.10 Communications Systems Development

Session Organizer: Timothy Pham, Jet Propulsion Laboratory, Caltech

4.1001 A X/X Spread-Spectrum Transponder for Secure Communication

L. Simone, F. De Tiberis, F. Barletta, D. Gelfusa, S. Cocchi, F. Argentieri, R. Viola, I. Martinazzo, M. Delfino, P. Panella, F. Felici, R. Novello, M. C. Comparini (Alcatel Alenia Space – Italy)

Aim of this paper is to provide an overview of Alcatel Alenia Space – Italy (AAS-I) Spread-Spectrum Transponder platform placing emphasis on its advanced features for secure Telemetry, Tracking & Command (TT&C) applications.

4.1002 The Koreasat 5 Secure Communication System: Design, Development & Performance

R. Novello, L. Simone, F. De Tiberis, M. Parisse, S. Paolucci, F. Barletta, D. Gelfusa, S. Cocchi, D. Fiore, R. Viola,I. Martinazzo, G. Lippolis, A. Bernardi, F. Autelitano, N. Salerno, M. Delfino, P. Panella, F. Felici, V. Piloni, M. C. Comparini

This paper presents the Koreasat 5 secure communication system that has been design and developed by Alcatel Alenia Space – Italy (AAS-I) for Agency for Defense Development – South Korea.

4.11 Communication System Analysis & Simulation

Session Organizer: Yogi Krikorian, The Aerospace Corporation

4.1101 Link Analysis for BILSAT-1

Ali Telli and Alphan Es (The Scientific and Technological Research Council of Turkey)

BILSAT-1, a 130 kg enhanced micro satellite, is Turkey`s first Low Earth Orbit Earth (LEO) observation satellite. The satellite project was started in August 2001 at Surrey Satellite Technologies Limited (SSTL)`s facilities in Guildford, UK and BILSAT-1 was launched successfully from Plesetsk Cosmodrome, Russia in 27 September 2003. The main objective of the mission is remote sensing. The communications subsystem is a core system for Earth observation satellite. It is generally used for telemetry/ tele-command signaling, software uploading and image/data transfer. The BILSAT-1 communications subsystem is composed of VHF/UHF (amateur space band) and S-Band (commercial space band). Link analysis is...

4.1102 Dynamic Proximity Communication Link Analysis Tool for Orbiting Satellites and Ground Assets on Mars

ogi Y. Krikorian, Milton K. Sue, Giadira V. Leon, Lamont Cooper, Sieu K. Do, Rajendra Kumar, David Taggart, Debra L. Emmons, Donald J. Dichmann, John P. McVey, and Eric T. Campbell (The Aerospace Corporation)

A dynamic proximity link analysis tool developed by The Aerospace Corporation is described in this paper. Given appropriate link budget parameters, the tool can return the data throughput for proximity links from ground assets to communications satellites. In order to determine the data throughput, the tool calculates the link margin as a function of time and determines the variable data rate(s) achievable as a function of time. Given any time period, the tool is then able to compute the total data throughput based on the data rate computations. Given a spacecraft's trajectory, the location of the ground asset, antenna gain...

4.1103 Weather Related Continuity and Completeness on Deep Space Ka-band Links: Statistics and Forecasting

Shervin Shambayati (Jet Propulsion Laboratory)

While the performance of various methods for Ka-band link design in term of data return has been well-understood, questions have remained about the completeness and continuity performance of the link. In this paper the concept of link ``stability`` as means of

measuring the continuity of the link is introduced and through it, along with the distributions of ``good`` periods and ``bad`` periods, the performance of the proposed Ka-band link design method using both forecasting and long-term statistics has been analyzed. The results indicate that the proposed link design method has relatively good continuity and completeness characteristics.

4.1104 Telemetry Recovery and Uplink Commanding of a Spacecraft Prior to Three-Axis Attitude Stabilization

Jonathan R. Bruzzi, J. Robert Jensen, Karl B. Fielhauer, Darryl W. Royster, Dipak K. Srinivasan (The Johns Hopkins University Applied Physics Laboratory)

After separation from the launch vehicle, a spacecraft's Guidance and Control system typically orients the spacecraft autonomously into a three-axis stabilized attitude for non-spinners. If an anomaly occurs, or if the spacecraft fails to orient itself appropriately, the Mission Operations team will want to observe spacecraft telemetry or may even be required to command the spacecraft before attitude stabilization. This paper addresses the capability of the Deep Space Network and Universal Space Network receivers to recover telemetry and of a Small Deep-Space Transponder to register valid uplink commands in a tumbling spacecraft situation.

4.12 Advanced Network Architectures for the National Airspace System

Session Organizer: Jack Burbank, The Johns Hopkins University Applied Physics Labor

4.13 Wideband Communications Systems

Session Organizer: Dave Taggart, The Aerospace Corporation
Session Organizer: Gary Goo, The Aerospace Corporation

4.1301 Use of Trellis-Coded Modulation for Gigabit/sec Transmissions over W-Band Satellite Links

Claudio Sacchi, Anelia Grigorova (University of Trento);

In this work, we are trying to challenge a very ambitious goal, i.e. to reach a pure data rate of 1Gb/s in a point-to-point W-band upstream LEO satellite connection, with a low bit-error rate. Non-ideal behaviors of the W-band physical layer have been realistically simulated. A transmission solution based on a robust Trellis-Coded Modulation (TCM) has been simulated in order to exploit efficiently the available bandwidth. Simulation results have shown the concrete possibility of reaching the Gb/s connectivity, provided that an accurate design of the TCM modulation scheme is addressed.

4.1302 On a Method to Establish Satellite Links for Dynamic Bandwidth Allocation

Vijitha Weerackody, Enrique G. Cuevas, Lino Gonzalez (The Johns Hopkins University Applied Physics Laboratory)

This paper examines the bandwidth and power allocation problem for a Multi-Frequency Time Division Multiple Access (MF-TDMA) based satellite communication system and presents a method to optimize the use of bandwidth and power at the satellite transponder. The constraints that are examined are: power and bandwidth limitations at the satellite transponder, terminal EIRP spectral density mask determined by regulatory and standards bodies, and a minimum data rate that should be supported by all terminals. Practical methods for realizing the resource allocation problem are discussed.

4.1303 Assessing the Performance of Packet Retransmission Schemes Over Satellite Links

James Hant, Donald Lanzinger, Dean Sklar (The Aerospace Corporation)

Satellite links are often characterized by scarce bandwidth, long delays, and fading. Next-generation, packet-switched satellite networks will increasingly use packet retransmission strategies because they can greatly improve the performance of packets sent over satellite links when errors are bursty due to fading. This paper presents a methodology for assessing the performance of various packet retransmission schemes over satellite links that may include channel fading, forward error-correction coding, and channel interleaving.

To validate the approach, a study is conducted that simulates how three types of packet retransmission strategies perform over a satellite link that has a Rayleigh fading channel and turbo-coder.

4.1304 Improved Antenna-Array Multi-User OFDM in Slow-Fading Frequency-Selective Channels

Thomas Ketseoglou (California State Polytechnic University, Pomona)

Oversampling is introduced as a very efficient way to improve the performance of multi-user OFDM in frequency selective, slow fading multipath channels. Both independent and correlated antenna arraya are considered. We show gaind of several dB upon applying this oversampling concept at both the channel estimation and data detection modes of the system.

4.1305 Modeling and Simulation of Amplifier Nonlinearities for Single 8-PSK Modulated Signal Input

David Taggart, Rajendra Kumar, Srini Raghavan, Gary Goo, Nick Wagner, Joseph Chen, and Yogi Krikorian (The Aerospace Corporation)

The performance of band limited M-ary PSK communication systems is impacted by amplifier nonlinearities. It is critical to precisely model high-power amplifiers (HPA) to ascertain the bit error rate (BER) performance of M-ary PSK communication systems, which are band limited. State-of-the-art simulation techniques can be employed to exactly ascertain intersymbol interference and its degradation on BER. In this paper the HPA input is a single 8-ary PSK modulated signal employing raised cosine filter shaping. The simulation results encompass spectral distortion considerations and BER plots. Eye diagrams, constellation figures, cross correlation plots, and timing diagrams are used to illustrate results.

4.1306 Simulation Study of Wideband Interference Rejection using STAP

Walter Au, Lijia Chen, Kenny Loo, Aldous Pabon, Yao Xiao, H. K. Hwang (California State Polytechnic University, Pomona)

Space Time Adaptive Processor(STAP) array antenna systems are discussed in this paper for suppressing the wideband interferences. To avoid a signal distortion STAP system with constraint is also considered and its performance is tested by computer simulation. Simulation results based on different processing algorithms(Applebaum, LMS, Sample Matrix Inversion [SMI]) are compared with the theoretical calculations. Different interference and noise scenarios are presented in this paper.

4.14 Advanced Communication Signal Processing

Session Organizer: Dave Taggart, The Aerospace Corporation
Session Organizer: Rajendra Kumar, The Aerospace Corporation

4.1401 Probability Mass Functions for de Bruijn Weight Classes

Gregory L. Mayhew (Boeing Phantom Works)

The de Bruijn sequences are full period shift register sequences with good randomness properties. The presented method used relationships between short cycles of progressively increasing lengths and combinatorial impacts to provide high resolution estimates of the probability mass functions for the weight class distributions of these sequences.

4.1402 Mitigation of Multipath Effects in OFDM Systems using Quantized State Adaptive Equalizers

Rajendra Kumar, Mubeen Khan (California State University, Long Beach)

This paper presents results on the performance of various equalizer algorithms when applied to the OFDM link operating in a severe multipath environment. The algorithms that are compared include the recursive least squares (RLS) and quantized state (QS) algorithms. While the RLS algorithms are more familiar to the engineers in this field, a set of a number of algorithms termed QS algorithms have also been invented earlier by the first author of this paper and have certain advantages in terms of computational efficiency and numerical robustness. A number of simulation examples are presented showing the bit error rates achieved.

4.1403 Effect of Nonlinear Amplification on Turbo Coding Gain

Eugene Grayver (The Aerospace Corp)

This paper presents results obtained from an end-to-end, proof-of-concept system that integrates a multi-constellation modem, turbo coding, and a nonlinear traveling wave tube amplifier (TWTA). Multilevel modulation schemes make it possible to provide high speed data communications in a limited amount of spectrum. This constraint is especially important for the power amplifier, which is typically a nonlinear device. Forward error correction based on turbo codes provides a solution for the problems described above, and improves the BER by increasing the noise margin by over 5 dB. This paper presents measured BER curves for different modulations and turbo codes, taken at...

4.1404 Efficient Modeling and Simulation of Nonlinear Amplifiers

Victor S Lin, Alberto Arrendondo, Jason Hsu (The Aerospace Corporation)

The analytical study of a system consisting of linear and nonlinear devices is often intractable and thus simulation is usually used to determine performance of such systems. An important aspect in the simulation of a nonlinear system is the selection of the sampling rate. A systematic way to determine the sufficient (or optimal) upsampling factor for simulation of a communication system with a nonlinear system and a pulse-shaping filter will be presented. We will also show how a nonlinear system can be implemented using a hardware co-simulation technique.

4.1405 Power Control Algorithm and Architectures for Fading Communication Channels

Rajendra Kumar (The Aerospace Corporation)

The present closed-loop power control algorithms in CDMA and UMTS ignore the round-trip delay incurred in the measurement of the received signal power. However, the round-trip delay for the case of geostationary satellite links is not negligible compared to the inverse channel fading bandwidth. This paper describes an algorithm based on an adaptive nonlinear predictor, which explicitly takes into account the propagation delay. The paper presents many simulation examples on the performance of the new power control architecture and algorithm showing that the residual loss due to fading is made relatively negligible, compared to the case of nonfading channels.

4.1406 Analysis of FM Demodulator Output Noise with Applications to the Space Lift Range System

Rajendra Kumar (The Aerospace Corporation)

This paper presents an analysis of the performance of the FM demodulator when the input signal-to-noise power ratio (SNR) at the demodulator input is below the FM threshold. The analysis is based on the probability distribution of the FM demodulator outpu

4.1407 A Parameterized Model for Efficient Over-Sampled Filter Bank Architectures

Waleed Namoos

There is much literature on maximally decimated filter banks, polyphase structures and specific areas of interest such as filter optimization techniques for perfect or near perfect reconstruction systems. There is less on the broader topic of architectures for hardware implementations. In this paper, a more basic foundation is laid for over-sampled filter banks along with their practical considerations. The objective is a universal architecture for efficient hardware implementation of DFT filter banks, whether over-sampled or critically sampled. To that end, a parameterized model that is, for the most part, independent of filter and optimization techniques will be proposed.

4.15 Global Navigation Satellite Systems

Session Organizer: Steven Lazar, The Aerospace Corporation

4.1501 Characterizing the Impact of Precision Time and Range Measurements on Network Position Solutions

Lt Kendra L.B. Cook (USAF); John F. Raquet, Capt Richard Beckman (Air Force Institute of Technology)

There is a strong desire to improve the ability to determine the relative position of a network of vehicles (such as aircraft, tanks, troops, etc). This research uses two-way time-transfer (TWTT) measurements, which are already being used for precise relative time measurements, to improve relative positioning of a vehicle network. This research characterizes the impact of using TWTT measurements to improve positioning of vehicle networks. The results show that including TWTT measurements in particular scenarios can reduce the 3-dimensional positioning errors by 11-42% and reduce the relative clock errors from 15% to over 99%.

4.1502 Spread Spectrum Codes for GPS L5

Srini H. Raghavan, Mark Shane, and Robert Yowell (The Aerospace Corporation)

An important consideration in the design of a spread-spectrum signal for Code Division Multiple Access (CDMA) applications such as in GPS is to select codes to minimize what is known as CDMA noise. The code selection process can be very tedious, depending on the number of codes needed and the number of codes available in a given code set. Code balance, autocorrelation sidelobe peak, cross-correlation peak, and spectral line distributions are some of the measures available in the code selection process, and these measures are not necessarily independent. In this paper we give the details of the code properties and...

4.16 Software Defined Radio Systems and Technology

Session Organizer: Eugene Grayver, The Aerospace Corporation

4.1601 Adaptive Two-Channel Automatic Gain Control System

Alexander Utter, Henry Chen, Shane Ouchi, David Money Harris, Amanda Rainer, Keane Kaneakua, and Chris Prounh (Harvey Mudd College); Samuel S. Osofsky (The Aerospace Corporation)

A new method is proposed for enhancing the performance of automatic gain control systems coupled with analog-to-digital converters (ADCs). This approach is focused on increasing dynamic range in applications where increasing ADC resolution is impractical. This novel approach utilizes two input channels in order to aggressively enhance sensitivity while remaining responsive to rapid changes in input signal power. For modest rates of input power change, signal- to error-power ratios can be enhanced by 6 dB or more. A methodology for selecting control parameters, algorithms for adjusting to input characteristics in real time, and results from a functional prototype are discussed.

4.1602 Influence of Weight Function Nonorthogonality on Sampling with Internal Filtering

Gennady Y. Poberezhskiy (Raytheon); Yefim S. Poberezhskiy (Rockwell Scientific)

Properties of novel sampling and reconstruction techniques with internal filtering are determined by their weight functions. Practical and theoretical restrictions imposed on these functions are considered. It is shown that adequately selected weight functions allow radical improvement of equipment performance; however, it is difficult to satisfy complex practical requirements for these functions. Mathematical restrictions for weight functions are loose because in practice, sampling frequency is higher than the Nyquist rate. It is shown that the weight functions should not necessarily be orthogonal or meet Riesz conditions. Many imperfections of antialiasing filtering within the passband can be compensated after A/D conversion.

4.17 Next-Generation Airborne Communication Networks

Session Organizer: William Kasch, JHU/APL

4.18 Advanced Communications, Navigation, & Surveillance Technology for National Airspace

Session Organizer: Denise Ponchak, NASA Glenn Research Center

4.1801 NASA Study for Establishing Baseline Requirements for Future Terminal Airspace CNS Systems

Chris A. Wargo (Computer Networks & Software, Inc); Rafael Apaza (Federal Aviaton Administration)

One of the NASA Glenn Research Center (GRC projects is performing the research and development on a robust, next-generation, wireless, wideband, air/ground communications technologies that will enable the significant increase in terminal area communications to support aircraft traffic growth. The first step of the research has been to conduct a requirements and technology assessment study of CNS systems existing and planned for a Class B and Class C airspace (Miami and Fort Lauderdale Airports). This paper focuses on communications carried on by the Federal Aviation administration (FAA), Airlines, Fix Base Operators, Security Agencies, passengers and other organizations.

4.1802 Traffic Management Automation for Non-Towered Airports

John Sorensen, Mark Peters, and David Schleicher (Sensis Corporation)

To increase flight operations capacity to meet future air transportation needs, a means must be found to provide Air Traffic Management (ATM) services for increased safety and throughput at the thousands of underutilized non-towered airports across the nation. Towers are expensive to build, maintain, and operate so there is significant economic incentive to find alternate automatic solutions to fulfill this ATM need. This paper addresses this need by describing the requirements and on-going research to develop ATM automation and cockpit technologies in lieu of providing manned towers at these airports.

4.1803 Efficient Algorithm for Optimal Scheduling of Aircraft Arrivals at Congested Airports

Aditya Saraf, Gary Slater (University of Cincinnati)

In this paper, we present a two-level control system for Optimal Traffic Flow Management. The outer control module will take a large-scale view of the NAS and use a spatially discretized Eulerian model for the NAS by dividing it into control volumes and characterizing all the aircraft in these control volumes by their aggregate flow properties. The inner control module will take in these flow commands from the Eulerian module as reference inputs and will use hybrid aircraft models for selecting controls for each aircraft within a control volume so that commanded flows are achieved by generating optimal aircraft trajectories.

4.1804 European A-SMGCS: the Challenge of Milan-Malpensa Airport in the Context of EMMA Project

Daniele Teotino, Marina Ruggieri (University of Rome "Tor Vergata"); Antonio Nuzzo (ENAV SpA)

The paper describes the status and the future steps of the A-SMGCS implementation in Milan-Malpensa airport putting emphasis on the upcoming on-site verification and validation activities. These activities are carried out in the context of Airport Movement Management by A-SMGCS (EMMA) project aiming to harmonise A-SMGCS implementation at European level.

4.1805 Emerging Definition of Next-Generation of Aeronautical Communications

Robert J. Kerczewski (NASA Glenn Research Center)

Aviation continues to experience rapid growth, leading to new efforts to develop methodologies and infrastructures to enable transformational air traffic management systems to enable that growth. This will require better communications linking airborne and ground-based elements. The technologies for next-generation communications, the required capacities, network interconnectivity, frequency spectrum of operation, and global interoperability are receiving increased attention. Major planning and development efforts are defining the transformed airspace of the future. This paper will review the features,

approaches, and activities of several representative planning and development efforts, and identify the emerging global consensus on requirements of next generation aeronautical communications systems.

4.1806 Concept for an Integrated National Surveillance and Data Communication Infrastructure

Todd A. Donovan (Sensis Corporation)

This paper identifies the requirements for future surveillance and data communication for the next generation air transportation system. It explores how key capabilities, such as 4D trajectory negotiation, drive the system requirements and design. The paper explores the need for a secure, transactional data link along with the need to maintain compatibility with existing transport class, general aviation and military equipage. The proposed multilateration, ADS-B and data link concept provides a robust foundation for future capability while delivering tangible benefits today.

4.1807 A Network-Centric Approach to Enhanced National Airpace Security

Robert J. Stamm, Yolanda McClease, Anthony J. Jagodnik (Raytheon)

Enhanced, inter-agency situational awareness, combined with improved collaboration between various law enforcement, military, and civilian automation systems is required to improve the homeland security of the US national airspace system. This paper reviews approaches to reducing response times and uncertainty during the detection and investigation of airspace security threats. This paper describes Raytheon's participation in a partnership with government and industry stakeholders that are carrying out research and development to define the requirements for future improvements to advance air traffic security.

4.1808 Fundamental Issues in Systematic Design of Airborne Networks for Aviation

Yang Wang (Lockheed Martin); Yiyuan J. Zhao (University of Minnesota)

A unique challenge to the proper design of airborne networks for civil aviation is the dynamic coupling between airborne networks and flight vehicles. This coupling directly affects the operations and performances of both the networks and the vehicles. An appropriate method of airborne network design must consider its interactions with vehicle flight maneuvers and vice versa. In this paper, fundamental issues in the systematic design of airborne networks are addressed. We particularly focus on the issues that cover various aspects of the design such as establishing the airborne network, maintaining the network, and evaluating the performances of the network.

4.1809 Air to Air Communication Protocol

Arjan Durresi, Vamsi Paruchuri (Louisiana State University); Leonard Barolli (Fukuoka Institute of Technology); and Raj Jain (Washington University in St. Louis)

We present Air to Air Communication (AAC), a wireless protocol designed for communication among airplanes as well as airplanes and control centers. AAC enables the broadcast of emergency and surveillance information such as realtime video over the network even in presence of adverse conditions such as coordinated terrorist attacks. AAC is very robust. AAC minimizes the number of retransmissions and therefore reduce the collisions, which could considerably delay transmissions and disrupt the communications during emergency situations. AAC performs very well in highly dynamic ad hoc networks of airplane. AAC has the potential to significantly enhance the security of the homeland by closely monitoring the airplane which, if hijacked by terrorists or criminals.

4.1810 Modular, Cost-Effective, Extensible Avionics Architecture for Secure, Mobile Communications

William D. Ivancic (NASA Glenn Research Center)

Current onboard communication architectures are based upon an all-in-one communications management unit. This unit and associated radio systems has regularly been designed as a one-off, proprietary system. As such, it lacks flexibility and cannot adapt easily to new technology, new communication protocols, and new communication links. This paper describes the current avionics communication architecture and provides a

historical perspective of the evolution of this system. A new onboard architecture is proposed that allows full use of commercial-off-the-shelf technologies to be integrated in a modular approach thereby enabling a flexible, cost-effective and fully deployable design.

4.1811 A Real-Time Communication Framework for Wireless Sensor-Actuator Networks

Michael R. Lyu (The Chinese University of Hong Kong)

Wireless sensor-actuator network comprises of a group of distributed sensors and actuators that communicate through wireless links. Sensors are small and static devices with limited power, computation, and communication capabilities for observing the physical world. Actuators are equipped with richer resources, able to move and perform appropriate actions. We designed a real-time communication framework to support event detection, reporting, and actuator coordination for wireless sensor-actuator network, exploring the timely communication and coordination problems among the sensors and actuators. Moreover, we proposed two self-organized and distributed algorithms for event reporting and actuator coordination. Some preliminary results are presented to demonstrated.

4.1812 Enhanced ADS-B Research

Ken Samuelson (Sensis Corporation)

Automatic Dependent Surveillance-Broadcast (ADS-B) is emerging as an advanced aviation technology that provides situational awareness within the aircraft that was previously available only on the ground. Pilots and ground personnel have begun to benefit from this technology but further benefits from technological improvements can still be realized. These improvements include security, increased data capacity, and advanced applications (4D trajectory and data exchange). This paper provides insight into the research that is currently being performed by Sensis Corporation in cooperation with NASA Glenn Research Center to provide enhancements to the ADS-B UAT (Universal Access Transceiver) data link.

4.1813 Techniques for Ensuring Co-existence Between B-VHF and Legacy VHF Systems

Sinja Brandes, Ivan Cosovic, Michael Schnell (German Aerospace Center)

A promising approach for future air traffic control (ATC) is the multi-carrier based broadband communication system B-VHF operated in the very high frequency (VHF) band. In order to allow for a gradual in-band transition from current to future ATC communication system the B-VHF system uses an overlay concept, i.e. it coexists with the current systems in the same frequency band. The two main issues to be solved for a successful co-existence are reduction of out-of-band radiation of the B-VHF transmit signal as well as interference mitigation at the B-VHF receiver. In this paper, methods for ensuring this co-existence are investigated.

4.19 Advanced Navigation Systems for Surface, Air, and Space Applications

Session Organizer: Chris Bartone

Track 5: Optics, Electro-Optics and Lasers

Track Organizer: David Tratt, Jet Propulsion Laboratory, Caltech
Track Organizer: Edward Watson, Air Force Research Laboratory, Sensors Directorate

5.01 Large Optics in Space

Session Organizer: H. Philip Stahl, NASA
Session Organizer: Lee Feinberg, NASA Goddard Space Flight Center

5.0101 Evaluating alternative architectures for lightweight space telescopes using parameterized models

Scott A. Uebelhart, Deborah Howell and David W. Miller (Massachusetts Institute of Technology)

An approach to the conceptual design of next-generation telescopes is proposed using parameterized models to evaluate architectures and for identifying combinations of advanced technologies to meet mission requirements. The models can be used to automatically generate multiple unique realizations of a system, including finite element models, based on high-level design variables. Following this, a complete dynamic analysis is performed on each realization, outputting performance and system metrics. A trade space analysis is run by varying key variables in the design space, and the superior architectures from over 1500 spacecraft realizations are identified.

5.0102 Clear Aperture Design Criterion for Deformable Membrane Mirror Control

Michael J Shepherd, Richard G Cobb, William P Baker (Air Force Institute of Technology)

Active lightweight continuous mirrors, such as deformable membrane mirrors, provide the capability to form conjugate surfaces effective for removing atmospheric distortions of an incoming wavefront. This paper provides design criteria for establishing achievable surface deflection performance inside of a “clear aperture” region for a pre-selected number of desired Zernike polynomials, and a number of retained quasi-statically-actuated vibration mode shapes. The methodology, coined the ``modal transformation method" by the authors, is contrasted with a direct projection method in an applied example performed on a MSC.Nastran non-linear finite element model of a piezoelectric-actuated deformable membrane mirror.

5.0103 Space Power Facility for Testing Large Space Optical Systems

Jerry Carek (NASA Glenn Research Center)

The Space Power Facility is the world’s largest space simulation test facility with a test chamber that is 30.5 m (100 ft) in diameter by 37.2 m (122 ft) high. Most of the design features of the facility provide unique characteristics that are ideally suited to meet the requirements of large space optical system thermal/vacuum testing. Future large space optical systems will require a facility that can handle and test large, delicate hardware in a clean, low vibration environment. This paper describes the facility’s unique characteristics and systems and how they meet these requirements.

5.0104 Architectures for Space Astronomical Telescopes Using Fresnel Optics

Jonathan Arenberg, Amy Lo (Northrop Grumman Space Technology)

This paper introduces architectures for a large aperture telescope for space astronomy using a Fresnel optic as the primary. Systems built around Fresnel optics hold the possibility of drastically reducing mission costs. The use of a Fresnel optic allows a light weight primary lens which results in lighter systems, which in turn can be flown on smaller, less expensive launchers. The key issue of mitigation of the intrinsic chromatic aberration will be discussed in detail. It will be shown that architectures based on Fresnel optics can be considered viable and should be considered in the technology selection for future missions.

5.02 Photonic Technologies for Aerospace Applications

Session Organizer: Andrew Pirich, Photonics Technology Center
Session Organizer: Edward Taylor, International Photonics Consultants

5.0201 Fabrication and Characterization of Large-Area 3-D Photonic Crystals

F. B. McCormick, J. G. Fleming, S. Mani, M. R. Tuck, J. D. Williams, C. L. Arrington, S. H. Kravitz, C. Schmidt, G. Subramania, J. C. Verley, A. R. Ellis, I. El-kady, D. W. Peters, M. Watts, W. C. Sweatt, J. J. Hudgens (Sandia National Laboratories)

Sandia National Laboratories is developing several methods to fabricate large area full bandgap (3D) photonic crystal materials. These materials offer a means to precisely engineer the electromagnetic reflection, transmission, and emission properties of surfaces over wide angular and spectral ranges. However, very few 3D photonic crystals have been successfully demonstrated with areas larger than 1 cm2. Large sheets of photonic bandgap (PBG) structures would be useful as hot or cold mirrors for passively controlling the temperature of satellites and may also find application in thermophotovoltaic energy generation and scavenging, as well as in wide field of view spectral filtering.

5.0202 Investigation of Millimeter Wave Parametric Generation from a THz Photonic Band Gap Device

Yuchuan Chen and Mark Cronin-Golomb (Tufts University); Lei Zhang and Jing Zhao (Agiltron Inc); James J. Foshee (Air Force Research Laboratory);

We present a PBG structure design for THz wave parametric generation. This PBG device has optical properties very close to that of a bulk crystal in the near infrared, but photonic crystal features in the THz range, such as structural dispersion, which allows placement of the phase matched pump wavelength in the near infrared to eliminate two-photon absorption of the pump and signal beams. The added design flexibility also allows the use of the most efficient crystal orientations.

5.0203 High-Resolution Liquid Crystal Spatial Light Modulators for Adaptive Optics

Jason D. Schmidt (University of Dayton)

Liquid crystals (LC) have many applications in optics. Many electro-optical devices, like LC spatial light modulators (SLMs), take advantage of electrically controllable birefringence in LCs. LC SLMs are amazingly flexible devices for controlling the phase and amplitude of light. Consequently, LC SLMs are being used for such techniques as wavefront sensing, emulating atmospheric turbulence, wavefront correction, beam steering, and holography. These techniques are often used in aerospace applications like laser weapons, free-space optical communications, satellite tracking, and satellite imagery. This paper highlights the use of LC SLMs for wavefront correction in a laser communication system and shows simulation results.

5.0204 Vertical Cavity Surface Emitting Lasers for Spaceflight Multi-Processors

Laurence E. LaForge, Jeffrey R. Moreland (The Right Stuff of Tahoe); Raymond G. Bryan (Synergy Technology); M. Sami Fadali (University of Nevada, Reno)

The vertical cavity surface emitting laser, or VCSEL, empowers interprocessor communication for grids of spaceborn computers. We quantify the scalability of VCSEL channels, implemented to achieve fault tolerance and connectivity tuned from sparse to dense. We illustrate with grid computers whose fault tolerance can be tuned from a worst-case constant, to a probabilistic constant fraction, to a worst-case constant fraction of all nodes. We synopsize the device integrity of VCSELs in a radiation-harsh spaceflight environment, and conclude by describing multi-processor prototypes for comparing alternative deployments of VCSELs: i) fiber waveguides; ii) photonics crossbars and backplanes; iii) direct, processor-to-processor beams.

5.0205 Beam Steering in Photonic Crystal Vertical Cavity Semiconductor Laser Arrays

Kent Choquette (University of Illinois)

Coherently coupled arrays of vertical cavity surface emitting lasers (VCSELs) may be useful in a variety of applications including laser radar and optical communications. A

method for providing optical confinement is the introduction of a two-dimensional photonic crystal pattern with multiple defects. A major achievement of this work is coherent coupling between the defect cavities, with both out-of-phase and in-phase coherent coupling. We show the relative phase difference between the defect cavities can be varied with injection current to acheive electronic beam steering.

5.03 Optics and Photonics Packaging for Space

Session Organizer: Andrew Shapiro, Jet Propulsion Laboratory, Caltech
Session Organizer: Raphael Some, Jet Propulsion Laboratory, Caltech

5.04 Free-Space Optical Communications

Session Organizer: Hamid Hemmati, Jet Propulsion Laboratory, Caltech
Session Organizer: Stephen Townes, Jet Propulsion Laboratory, Caltech

5.0401 Feasibility Analysis of a HAP-LEO Optical Link for Data Relay Purposes.

Mirko Antonini, Silvello Betti, Valeria Carrozzo, Elisa Duca, Marina Ruggieri (University of Rome "Tor Vergata")

The aim of the paper is to prove the technical feasibility and the advantages of a joint RF and optical communication system. The reference scenario foresees the use of a HAP (High Altitude Platform) or multiple Haps for data relay purposes.Optical space communications offer a wide bandwidth and low interference channel. By the use of this system, it is possible to increase the amount of information downloaded by a High Altitude Platform from a LEO satellite, reaching data rate up to 10 Gbit/s .

5.05 Laser Remote Sensing

Session Organizer: Gary Spiers, Jet Propulsion Laboratory, Caltech
Session Organizer: Steven Beck, The Aerospace Corp.

5.0501 Spacecraft Hazard Avoidance Utilizing Structured Light

Carl Christian Liebe, Curtis Padgett, Jacob Chapsky, Daniel Wilson, Kenneth Brown, Sergei Jerebets, Hannah Goldberg, Jeffrey Schroeder (Jet Propulsion Laboratory)

Structured light is a method of remote sensing 3-dimensional structure of the proximity utilizing a laser, a grating, and a single regular APS camera. The laser beam is split into 400 different beams by a grating to form a regular spaced grid of laser beams that are projected into the field of view of an APS camera. The laser source and the APS camera are separated forming the base of a triangle. The distance to all beam intersections of the host are calculated based on triangulation. Distance accuracy of 4 cm and an operating range of 12 meter were demonstrated.

5.0502 Impacts of Upper Tropospheric Clouds on GPS Radio Refractivity

Grace S Peng, Robert W. Farley, John E. Wessel (The Aerospace Corporation); Manuel de la Torre-Juárez (Jet Propulsion Laboratory)

Atmospheric radio-refractivity profiles obtained from GPS occultation measurements are analyzed to provide temperature and water vapor profiles. These profiles are compared with measurements from a ground-based lidar that also produces temperature and water vapor profiles, and in addition, can sensitively detect the presence of and extinction due to aerosols. Comparison of these measurements demonstrates that with proper analysis of the radio occultation refractivities, detection of even thin cirrus clouds is possible. Currently, thin cirrus is not reliably detected by space-borne systems.

5.0506 The High Output Maximum Efficiency Resonator Developed for Long Life, Space-Based Altimetry

D. Barry Coyle (NASA-GSFC); Paul R. Stysley (American University)

We report on the status of the High Output Maximum Efficiency Resonator (HOMER), a prototype space-flight Nd:YAG, diode pumped, unstable resonator. HOMER, the 3rd generation of this design based on the High Efficiency Laser Transmitter, is a stand-alone oscillator that has achieved 2 billion 10 ns q-switched pulses at 17-15 mJ. In this

configuration HOMER achieves an excellent optical efficiency of 16%. It is currently the lead candidate for the Biomass Monitoring Mission (BioMM); a global vegetation instrument currently under design and pre-proposal at NASA-GSFC.

5.06 Novel Imaging Systems

Session Organizer: Bradley Duncan, University of Dayton
Session Organizer: David Wick, Sandia National Labs

5.0601 Multi-Spectral Foveated Imaging System

Brett E. Bagwell, David V. Wick (Sandia National Labs); Jim Schwiegerling (University of Arizona)

The development of sensors that are smaller, lighter weight and require less bandwidth is critical for the success of space-based and airborne imaging systems. One solution to this problem is foveated imaging, wherein a liquid crystal spatial light modulator is used to selectively enhance resolution in a wide field-of-view (FOV) imaging system. Selective enhancement decreases the bulk and complexity of the optical train, while simultaneously reducing data transmission and processing requirements. This enhancement is done modulo 2, as such it is inherently a monochromatic correction. In this paper, we propose to overcome that limitation by introducing a switchable polarization interference...

5.0602 Measuring a Deformable Mirrors Surface While Under Physical Vibrations

Christopher C. Wilcox, Jonathan R. Andrews, Sergio R. Restaino, Ty Martinez (Naval Research Laboratory); Freddie Santiago, Erick Roura (University of Puerto Rico – Mayagüez) Scott W. Teare (New Mexico Tech); Don M. Payne (Narrascape, Inc.)

This paper reports on the measurement and reconstruction using two algorithms of an Adaptive Tilt Mirror's reflected wavefront using a Shack-Hartmann wavefront sensor. The combined wavefront corrector consists of a deformable mirror mounted onto a fast steering platform. Reconstruction of the wavefront was performed using finite difference and finite element reconstructors for comparison. The Shack Hartmann wavefront sensor and the two types of software reconstructors provide a visualization of the mirror's surface.

5.0603 Diamond Milling of Micro-Optics

WC Sweatt, DD Gill, DP Adams MJ Vasile, and AA Claudet (Sandia National Labs)

A diamond mill (a tiny end mill) can cut aspheric lenses and mirrors with diameters smaller than 0.5 mm. The cutting tool has a two-dimensional shape and is spun about the axis of the surface to be cut. As the spinning tool is plunged into the substrate, it cuts a radially symmetric surface to sub-micron accuracies. Commercially available circular diamond tools can be modified to aspheric shapes using a focused ion beam. Fabrication examples will be presented and the optical performance of an array of micro-lenses will be described.

5.0604 Resolution Enhanced Sparse Aperture Imaging

Nicholas Miller, Bradley Duncan (University of Dayton); Matt Dierking (Air Force Research Laboratory)

The goal of multiple aperture imaging is to enhance resolution by increasing the effective aperture diameter while simultaneously minimizing the total image collection area. Provided is a description of several sparse aperture performance metrics and results of a computer study for several sparse aperture geometries, particularly minimum redundancy arrays. We have investigated the effects of varying both the number and relative spacing of sub apertures. The evaluation of these sparse aperture geometries, and their accompanying metrics, guide our present terrestrial imaging work as we explore the possibility of combining sub aperture images through post detection processing.

5.07 Image Processing

Session Organizer: Nevin Bryant, Jet Propulsion Laboratory, Caltech
Session Organizer: Stephen Cain, Air Force Institute of Technology

5.0701 Strategies for Hyperspectral Target Detection in Complex Background Environments

Michael T. Eismann (Air Force Research Laboratory)

The capability to rapidly detect and identify ground targets hidden in natural and man-made clutter over broad areas remains of high interest for defense applications, and is emerging as a critical component to counter-terrorism and homeland security missions. Recognizing the difficulty in establishing such a capability based on traditional, panchromatic imaging sensors in the electro-optical and infrared spectral region, the Air Force Research Laboratory (AFRL) has been investigating the added potential that spectral and polarimetric sensing methods provide. This paper provides an overview of some of the primary AFRL research interests and directions to address these limitations.

5.0702 Weighted Frame Averaging for Motion Compensation of Laser Radar Image Data

Lt Col Adam MacDonald (Air Force Institute of Technology)

This research seeks a new method to assign weights to each of the frames within an ensemble of LADAR images that has been previously registered using an arbitrary translational registration algorithm. Frames with poor registration are assigned low weights according to a maximum likelihood cost function, allowing such frames to be either discarded from the ensemble or re-registered using an alternate algorithm. The estimator is based on the underlying statistics of the intensity distribution of partially coherent illumination. Simulated and experimentally collected data is presented to support the development and performance of the misregistered frame detector.

5.0703 The Application of Inverse Filters to 3D Microscanning of LADAR Imagery

Ernest Armstrong (OptiMetrics Inc); Richard Richmond (Air Force Research Laboratory)

Microscanning is an effective technique for reducing aliasing and increasing resolution in 2D images produced by non-coherent imaging systems. Both the aliasing reduction and resolution enhancement are accomplished by increasing the effective spatial sampling interval through sub-pixel movements of the field of view on the detector array. In this paper the authors examine (using both simulated and real data) the application of microscanning on 3D coherent imagery (with application to 2D coherent imagery). The application of Inverse filtering techniques are also examined to resolve difficulties associated with blurring by the detector and optical systems. The effects of blurring by the detector...

5.0704 Joint Blind Deconvolution and Image Correlography via a Bayesian Image Reconstruction Algorithm

Stephen C. Cain (Air Force Institute of Technology)

Laser imaging through atmospheric turbulence is a challenging problem due primarily to turbulence close to the aperture. Amplitude measurements of the return beam in the plane of the aperture are immune to turbulence, but contain limited information about the Fourier phase of the target image. This paper suggests a method for using blind deconvolution of laser speckle degraded imagery together with correlography techniques in order to simplify the phase retrieval problem and produce coherent image reconstructions with spatial resolution not limited by the atmospheric conditions. The viability of the technique is demonstrated via computer simulation.

5.08 Electro-Optics Devices for Aerospace

Session Organizer: Franz Haas, Air Force Research Laboratory

5.0801 Responsivity and Lifetime of Resonant Cavity Enhanced HgCdTe Detectors

Justin G. A. Wehner, Charles A. Musca, Richard H. Sewell, J. M. Dell, and L. Faraone (The University of Western Australia)

Resonant cavity enhanced HgCdTe structures have been grown by molecular beam epitaxy, and photoconductors have been modelled and fabricated based on these structures. Responsivity has been measured and shows a peak responsivity of 8x10 4 V/W for a 50 x 50 square micrometer photoconductor at a temperature of 200K. The measured responsivity shows good agreement with the modelled responsivity across the mid-wave infrared window (3-5 micrometers). The measured responsivity is limited by surface recombination, which limits the effective lifetime to 15ns. The optical cut-off of the detector

varies with temperature as modelled. There is strong agreement between modelled peak responsivity and measured.

5.0802 Advanced Sun-Sensor Processing and Design for Super-Resolution Performance

John P. Enright, Godard (Ryerson University)

We analyze the performance of conventional and parametric super-resolution algorithms for estimating sun position in a spacecraft sun-sensor. Widely employed in other applications, we examine whether parametric algorithms can increase sensor performance without affecting the cost of the sensor system. Better than two-fold resolution improvements over high-accuracy traditional algorithms are observed in the presence of realistic system noise. Further tests establish that multiple-peak illumination patterns enhance resolution, while wide peaks generally are an impairment. These mask-dependent improvements are observed in both of the parametric algorithms and one of the traditional algorithms.

5.0803 An Analog Optical Computational Approach to RF Image Formation

Robert Bonneau, Franz Haas (Air Force Research Laboratory)

RF image formation is a computationally expensive process due to the excessive amount of instantaneous RF bandwidth required to form imagery for high resolution. As a result the size weight and power of traditional devices designed to compute imagery in RF apertures is quite high. We therefore propose a method that allows us to compute RF imagery using an analog fiber diffraction grating in conjunction with electro-optical modulators, traditional analog RF phase shifters and a spatial light modulator.

5.0804 Electro-Optical Signatures Comparisons of Geosynchronous Satellites

Tamara E. Payne, Stephen A. Gregory (Boeing LTS Inc.); Kim Luu (Air Force Research Laboratory)

The Air Force Research Laboratory has observed the color photometric signatures of geosynchronous (GEO) satellites since 1996. Recently, we have constructed models and a radiometric simulation in order to aid in understanding the physics of satellite radiometric signatures. We report on the results of the construction of models of GEOs and the comparison of the resulting simulated photometric signature from the models to empirical photometric data obtained of these satellites using CCD technology. We regard these models to be of “first order” in that they employ accurate basic sizes and shapes along with excellent reflectivity functions for typical spacecraft materials.

Track 6: Remote Sensing

Track Organizer: Lance Kaplan, U.S. Army Research Laboratory
Track Organizer: Peter Kahn, Jet Propulsion Laboratory, Caltech

6.01 Tracking Applications

Session Organizer: William Blair, Georgia Tech Research Institute
Session Organizer: Yaakov Bar-Shalom, Univ of Connecticut

6.0101 Simulations Studies of Multisensor Track Association and Fusion Methods

Lance M. Kaplan (Army Research Laboratory); William Dale Blair (Georgia Tech Research Institute); Yaakov Bar-Shalom (Univ. of Connecticut)

Recent work has developed maximum likelihood (ML) methods for track-to-track data association and estimation in a multisensor environment. The fusion engine uses this track information to determine which tracks associate to the same target and then computes a fused track to improve the accuracy of the state estimates. To this end, this paper introduces new methods to approximate the cross-sensor covariance matrices. The paper then uses computer simulations to assess the performance of the different association and estimation techniques that use different values for the cross-sensor error covariance (zero, exact or approximated).

6.0102 Sensor Resource Management Using Cost Functions

John E. Gray and A. Sunshine Smith-Carroll (Naval Surfare Warfare Center)

When integrating track data across multiple platforms, one tries to create a Super-Platform that has performance capability which is greater than an individual platform. The performance of the Super-Platform ideally would be the superposition of the individual performances of the single platforms. From an estimation perspective, one of the key problems blocking this is prediction which degrades significantly with time delays or bias which are caused by sensor misalignments and threat miss-modeling. While prediction functions can be accomplished seamlesslily in the background in a single ship environment, they become more problematic in a networked ship environment.

6.0103 ML-PDA Track Validation Thresholds

Wayne R. Blanding, Peter K. Willett, Yaakov Bar-Shalom (University of Connecticut)

The Maximum Likelihood Probabilistic Data Association (ML-PDA) algorithm, developed for Very Low Observable target tracking, provides candidate tracks that must then be validated or rejected. By comparing the Log Likelihood Ratio (LLR) at the parameter estimate to a threshold, validation is accomplished. Using extreme value theory, in the absence of a target this LLR obeys approximately a Gumbel distribution and not the Gaussian distribution previously ascribed to it, and false track rejection probability is obtained for a given threshold value. True track detection probability is obtained assuming this LLR obeys approximately a Gaussian distribution in the presence of a target.

6.0104 Vision-Based Relative Pose Estimation for Autonomous Rendezvous and Docking

Jed M Kelsey, Jeffrey Byrne, Martin Cosgrove, Sanjeev Seereeram, Raman K Mehra (Scientific Systems Company, Inc)

Relative pose estimation is a critical ability for many planned space programs and activities such as DARPA ASTRO, NASA MSR, and ISS/satellite assembly and servicing, which involve autonomous rendezvous and docking or other proximity operations. We present a model-based pose refinement algorithm, part of a suite of algorithms for vision-based relative pose estimation and tracking. Algorithms were tested using synthesized and real image sequences from high-fidelity simulation and hardware testbed environments. Testbed configuration, goals, and selected algorithm performance results are described. Benefits and drawbacks of the algorithm are discussed, and suggestions for future work are provided.

6.0105 Radar Measurement Noise Variance Estimation with Targets of Opportunity

Yaakov Bar-Shalom, Richard W. Osborne III (University of Connecticut)

In order to carry out state estimation from the noisy measurements of a sensor, the filter should have knowledge of the statistical characteristics of the noise associated with that sensor. This paper presents a method of determining the measurement noise variances of a sensor by using multiple IMM estimators while tracking targets whose motion is unknown. The likelihood functions are obtained for a number of IMM estimators, each with different assumptions on the measurement noise variances. Then a search is carried out to bracket the variances, resulting in estimates of the measurement noise variances of the sensor.

6.02 Probabilistic Assignment Techniques for Multiple Target Tracking

Session Organizer: Darin Dunham, Vectraxx

6.0201 Optimal Image Processing for Multi-Target Tracking of Dismounted Targets in an Urban Environment

Jon P. Champion, Juan R. Vasquez (Air Force Institute of Technology)

Dismounted targets can be tracked in urban environments with video sensors. Real-time systems are unable to process all of the imagery, demanding some method for prioritization of the processing resources. Furthermore, various segmentation algorithms exist within image processing, and each algorithm has an associated computational cost. Additional complexity arises in the prioritization problem when targets become occluded and when the targets are intermixed with other dismounted entities. The approach presented in this paper is to apply multi-target tracking techniques in conjunction with an integer programming optimization routine to determine optimal allocation of the video processing resources.

6.0202 Comparison of Soft and Hard Assignment ML Trackers on Multistatic Data

Peter Willett (University of Connecticut), Stefano Coraluppi (NURC), Wayne Blanding (University of Connecticut)

As opposed to the MLPDA, for whom associations between measurements and targets are yes/no decisions, for the PMHT they are actually the posterior association probabilities: they are "soft". The MLPMHT optimizes the PMHT likelihood function. Our results suggest that the MLPMHT is better. Not only is the concept of a "frame" of data less relevant for it than the MLPDA, and not only is optimization simpler; but it appears that it both works more robustly and is able to avoid contact starvation during periods of poor SNR. A nice feature that optimal multi-target data association is easy with the MLPMHT.

6.0203 Advances in the PMHT as a Network-level Composite Tracker

Darin Dunham (Vectraxx)

With single-frame tracking algorithms, only information that has been received to date is used to determine the association between tracks and measurements. These decisions are made based on available data and are not changed even when future data may indicate that the decision was incorrect. On the other hand, in multi-frame algorithms, hard decisions are delayed until some time in the future, thus allowing the possibility that incorrect association decisions may be corrected with more data. This paper, presents the ongoing results of research using the Probabilistic Multi-Hypothesis Tracker algorithm as a network-level composite tracker on distributed platforms.

6.03 Particle Filtering and Markov Chain Monte Carlo Techniques

Session Organizer: Petar Djuric, Stony Brook University
Session Organizer: Simon Godsill, University of Cambridge

6.0301 Comparison of EKF- and PF-based Methods in Tracking Maneuvering Targets

Monica F. Bugallo, Shanshan Xu, and Petar M. Djuric (Stony Brook University)

In this paper we address the problem of tracking of a high-speed maneuvering target which moves along a two-dimensional space. We investigate and compare several approaches based on the Bayesian methodology and propose various strategies to cope with the two models that account for the different regimes of movement. The advantages and

disadvantages of the considered algorithms are illustrated and discussed through computer simulations.

6.0302 The Marginalized Particle Filter in Practice

Thomas Schön, Rickard Karlsson, Fredrik Gustafsson (Linköping University, Sweden)

The marginalized particle filter is a powerful combination of the particle filter and the Kalman filter, which can be used when the underlying model contains a linear sub-structure, subject to Gaussian noise. This paper will illustrate several positioning and target tracking applications, solved using the marginalized particle filter. Furthermore, we analyze several properties of practical importance, such as its computational complexity and how to cope with quantization effects.

6.0303 Online Multisensor-Multitarget Detection and Tracking

William Ng, Jack Li, Simon Godsill (University of Cambridge)

In this paper we present an online approach for joint detection and tracking for multiple targets with multiple sensors using sequential Monte Carlo (SMC) methods. A full SMC context for track initiation and termination is used for target detection. Tracking of manoeuvring targets without using multiple-model approaches is also proposed. A central-level tracking strategy with multiple sensors is adopted, where the observations from all active sensors are fused together for detection and tracking. Computer simulations demonstrate that the proposed approach is robust in performing joint detection and tracking for multiple manoeuvring targets where the environment is highly cluttered with low target detection probability.

6.0304 Multi Target Direction-of-Arrival Tracking using Road Priors

Volkan Cevher, Rajbabu Velmurugan, James H. McClellan (Georgia Institute of Technology)

We present a multi target particle filter DOA tracker that can incorporate road prior information. The filter uses a batch of DOA`s to determine the state vector, based on an image template matching idea. We present two approaches for incorporating the road information. In the first approach, the road prior is injected at the weighting stage of the tracker. The second approach is based on modifying the state update function with a compound model, where a mixture of the constant velocity model and the road information is used.

6.0305 Meshfree Adjoint Methods for Nonlinear Filtering

Fred Daum, Mikhail Krichman (Raytheon)

We apply a powerful numerical approximation called the meshfree adjoint method to solve the nonlinear filtering problem. This algorithm exploits the smoothness of the problem, and hence we expect that this new algorithm will be superior to particle filters for many practical applications. The adjoint method is analogous to importance sampling in particle filters, but it is better for four reasons:(1) it exploits the smoothness of the problem; (2) it explicitly minimizes the errors in the relevant functional; (3) it explicitly models the dynamics in state space; and (4) it computes a corrected functional using the residuals and adjoint solution.

6.0306 Multiple Object Tracking Using Particle Filters

Artur Loza, M.H. Jaward, L. Mihaylova, N. Canagarajah and D. Bull (University of Bristol)

In this paper we propose a particle filter for multiple object tracking in video sequences. The track initialisation is embedded in the particle filter without relying on an external object detection scheme. The particle filter (PF) embeds a data association technique based on the joint probabilistic data association (JPDA) which handles the uncertainty of the measurement origin. The algorithm is able to cope with partial occlusions and to recover the tracks after temporary loss. The performance of the filter is evaluated on various real-world video sequences with appearing and disappearing targets.

6.04 Multisensor Fusion

Session Organizer: Marvin Cohen, IRTA - MCA
Session Organizer: Robert Lynch, Naval Undersea Warfare Center

6.05 Detection and Classification

Session Organizer: Peter Willett, University of Connecticut
Session Organizer: Tod Luginbuhl, Naval Undersea Warfare Center

6.0501 Extended Area Protection System (EAPS) Program Overview

Brian J. Smith, Roswell W. Nourse, James L. Baumann, George Sanders (US Army, RDECOM)

The U.S. Army's Aviation and Missile Research, Development, and Engineering Center (AMRDEC) is undertaking an Advanced Technology Objective (ATO) to provide active protection to U.S. forces against attack by Rockets, Artillery, and Mortars (RAM). Engaging and destroying RAM will reduce U.S. causalities, provide all freedom of movement, protect non-combatants, and safeguard military/civilian installations. Novel solutions are required to counter RAM cost effectively. This paper outlines activities being conducted under the EAPS ATO that are being investigated to protect U.S. interests against the RAM threat.

6.0502 Intelligent Identification Software Module (IISM) for the US Navys Combat Centers

Robert Richards, Richard Stottler, Coskun Tasoluk, Ben Ball (Stottler Henke Associates, Inc.)

Stottler Henke has developed and continues to enhance our automated intelligent software, which performs the tasks and decision making currently handled by the personnel manning the watch stations in the Combat Direction Center (CDC), the Task Force Combat Center (TFCC), on-board aircraft carriers, and other Navy ships. The Intelligent Identification Software Module (IISM) alleviates some of the burden placed on battle commanders by automating certain tasks, such as the management of historical data, disambiguating multiple track targets, assessing the threat level of targets, and even rejecting improbable data.

6.06 Hyperspectral Science and Signal Processing

Session Organizer: Alan Schaum, Naval Research Laboratory

6.0601 A Remedy for Nonstationarity in Background Transition Regions for Real Time Hyperspectral Detection

Alan Schaum (Naval Research Laboratory)

Inadequate adaptation can occur in hyperspectral systems when an airborne sensor encounters a physical transition area. We describe a two-component mixture model that gracefully grows the capabilities of deployed systems to adapt to transitions. After the parameters of a bi-modal Gaussian model are found, the detection model allows mixtures of two background components, with unknown mixing fraction estimated by a GLR test. Spectral whitening modules allow the simultaneous diagonalization of the covariance matrices of both primary mixture components. This generates only a small additional computational burden for all detectors, consisting of a standard Newton-Raphson algorithm applied to a polynomial function.

6.0602 A Statistical Approach to Quantifying Clutter in Hyperspectral Infrared Images

Oladipo Fadiran, Peter Molnar (Clark Atlanta University); Lance Kaplan (Army Research Laboratory)

A method to quantify clutter in hyperspectral infrared images is presented. Objects in a scene that may be mistaken for targets by an ATR are considered clutter. The aim is to obtain a measure which, indicates the inherent difficulty for an ATR to detect targets. We computed 129 image metrics for a database of images, and defined the measure as the combination of a subset of these metrics that correlates best with the amount of clutter in the images, which is established by ATR performance. The measure obtained from a varying number of sample images generalizes well for the entire database.

6.07 Radar/Sonar Signal Processing

Session Organizer: Ivars Kirsteins, NUWC
Session Organizer: Robert Lynch, Naval Undersea Warfare Center

6.0701 Analytical Results in Detecting Broadband Signals in Reverberant Dispersive Environments

Robert Lynch, Ivars Kirsteins, and James Kelly (Naval Undersea Warfare Center); Peter Willett (University of Connecticut)

In previous work, the utility of using broadband waveforms was investigated as a means of improving active sonar performance against slow moving or stationary targets in littoral waters. This work was motivated by the fact that, in principle, the use of a wide spectrum permits the design of waveforms with nearly ideal “thumbtack-like” ambiguity functions. Given that, the work reported in this paper discusses the extension of previous results by investigating coherence losses for an arbitrary time duration and bandwidth waveform. Further, additional results have been obtained to simulate time/frequency dispersion losses that are assumed to be multi-modally Gaussian distributed.

6.08 Space Based Radar Technology

Session Organizer: Andy Register, Georgia Tech Research Institute
Session Organizer: Peter Zulch, AFRL

6.0801 Transmit Waveform Diversity for Space Based Radar

Peter Zulch (Air Force Research Laboratory), Robert Hancock (CAESoft Corp.), William Moran, Sofia Suvorova, James Byrnes (Prometheus Inc.)

Space Baser Radar (SBR) is once again being considered for performing the Ground Moving Target Indication (GMTI) mission. Due to limited SBR transport size restrictions, satellite location and velocity, radar operating conditions, and earth rotation, resulting clutter Doppler spectral spread can be detrimental to radar Minimum Discernable Velocity (MDV) performance. This paper looks at several approaches to mitigate, in particular, the earth rotation effect. These approaches include mechanical antenna pointing, and waveform diversity with the objective of improving MDV performance.

6.0802 SBR Waveform and Processing Parameters as a Function of Array Distortion

Richard S. Pierro, Scott E. Parker (Technology Service Corporation), Richard Schneible, Yuhong Zhang, Abdelhak Hajjari (Stiefvater Consultants)

Structural distortions in large antennas have impact on antenna gain, sidelobe level and adaptive interference rejection. Partial compensation for the distortion of space-based radar (SBR) phased-array antennas and array-fed reflectors can be achieved by adjusting the phase-shifter settings to compensate for the distortion. This approach is effective in regaining the antenna gain and sidelobe levels, but the adaptive rejection of interference and clutter is much more complex. To evaluate the impact of mechanical distortion on GMTI performance, the full-dimension Space-Time Adaptive Processing (STAP) Matched Filter (MF) and the reduced-dimension joint-domain localized (JDL) algorithms were evaluated.

6.0803 Achieving Sub-Pixel Registration Accuracy for Radar Imagery.

Hanna Witzgall, Peter Gural (SAIC); Edward Mahen (USAF)

This paper describes a robust, and computationally efficient procedure to obtain sub-pixel registration accuracy. The new approach is based on the well-known phase correlation method. Important to the new process is the observation that the phase correlation matrix has unity rank. The reduced rank subspace employed is not based on the common eigenvector approach but on Reduced Order Correlation Kernel Estimation Technique (ROCKET) that maximizes the mutual information criteria. The performance results show that the new algorithm can achieve high registration accuracy with reduced computational complexity compared to several recently published sub-pixel registration algorithms.

6.0804 An Application of Advanced Spectrum Estimation to Multi-Channel Radar Detection and Location

William C. Ogle, Howard Mendelson (Science Applications International Corp.); Peter A. Zulch (Air Force Research Laboratory)

We apply ROCKET, a reduced-rank spectral estimator, to detect and localize moving targets with a multi-channel space radar system. Moving targets in a given range-Doppler cell exhibit a channel-to-channel phase difference; this is viewed as a spectral estimation problem. Since the target and clutter phase ramps are very close, a super-resolution approach is needed. Our method builds on previous work that employed a passive angle-of-arrival and alternating projections technique, which uses no other training data, unlike conventional STAP methods.

6.0805 A Rate Distortion Method for Waveform Design in RF Target Detection

Robert Bonneau (Air Force Research Laboratory)

Conventional RF image formation relies on a fixed waveform set that is based largely on obtaining maximum resolution for a given amount of bandwidth present in a waveform. However, the correlation process for a given waveform set varies widely depending on the cross correlation properties of the waveform and the geometry of the aperture interrogating the object to be detected. We propose a method that maximizes quality of the object being detected by first using an orthogonal basis to minimize the unwanted correlation response for the waveform. We then shape the frequency and temporal correlation response of the waveform for a given target using a rate distortion criteria and demonstrate the imaging and...

6.09 Interferometry and Large Optical Systems

Session Organizer: Peter Kahn, Jet Propulsion Laboratory, Caltech

6.0901 Progress in four-beam nulling: results from the Terrestrial Planet Finder Planet Detection Testbed

Stefan Martin (Jet Propulsion Laboratory)

The Terrestrial Planet Finder Interferometer (TPF-I) is a large space telescope consisting of four 4 meter diameter telescopes flying in formation in space. The Planet Detection Testbed has been developed to study the combination of the four beams of light from the telescopes in a twin nulling beam combiner which emulates the functionality of the space telescope. Recent results from the testbed include nulling of 4 input beams simultaneously at null depths of 250,000 to one and planet detection at a contrast ratio of one 2 millionth of the intensity of the star.

6.0902 Testing the TPF Interferometry Approach Before Launch

Gene Serabyn, Bertrand Mennesson (Jet Propulsion Laboratory)

One way to directly detect nearby extra-solar planets is via their thermal infrared emission, and both NASA and ESA are investigating cryogenic infrared nulling interferometers. Because of the high contrasts involved, and the novelty of the measurement technique, it is essential to gain experience with this technique before launch. Here we describe a simple ground-based experiment that can test the essential aspects of the TPF signal measurement and image reconstruction approaches by generating a rotating interferometric baseline within the pupil of a large single-aperture telescope.

6.0903 Development and Validation of High Precision Models for SIM Planetquest

Chris A. Lindensmith, H. Clark Briggs, Yuri Beregovski, V. Alfonso Feria, Renaud Goullioud, Yekta Gursel, Inseob Hahn, Gary Kinsella, Matthew Orzewalla, Charles Phillips ((Jet Propulsion Laboratory)

We present a description of the model development, some of the models, and their validation in the Thermo-Opto-Mechanical (TOM3) testbed of the SIM Planetquest mission. This testbed includes full scale brassboard optical components and the metrology to test them at the SIM performance requirement levels and validate the models.

6.0904 Results from the TOM3 Testbed: Thermal Deformation of Optics at the Picometer Level.

Renaud Goullioud, Chris A. Lindensmith, Inseob Hahn (Jet Propulsion Laboratory)

The Space Interferometer Mission requires thermal stability of the optical wavefront to the level of picometers in order to produce astrometric data at the micro-arc-second level. The Thermo-Opto-Mechanical testbed (TOM3) was developed to measure thermally induced optical deformations of a full-size flight-like beam compressor and siderostat. The Siderostat was installed in a temperature-controlled thermal shroud inside the vacuum chamber, creating a flight-like thermal environment. A Common Path Heterodyne Interferometer is used for the fine optical path difference measurements. Experimental data shows SIM required thermal stability of the test articles and good agreement with the model predictions.

6.0905 Engineering the LISA Project: Systems Engineering Challenges

Jordan P. Evans (Jet Propulsion Laboratory)

The Laser Interferometer Space Antenna (LISA) is a joint NASA/ESA mission to detect and measure gravitational waves. The systems engineering challenges of developing a giant interferometer, 5 million kilometers on a side, are numerous. Some of the key challenges are presented in this paper. The organizational challenges imposed by sharing the engineering function between three centers (ESA ESTEC, NASA GSFC, and JPL) are addressed. The issues and approaches to allocation of the noise and sensitivity budget terms are discussed. The approach to understanding the implications of science data analysis on the system is also addressed.

6.0906 The Science, Technology and Mission Design for the Laser Astrometric Test of Relativity

Slava G. Turyshev (Jet Propulsion Laboratory)

The Laser Astrometric Test of Relativity (LATOR) is a Michelson-Morley-type experiment designed to test the Einstein`s general theory of relativity in the most intense gravitational environment available in the solar system -- the close proximity to the Sun. By using independent time-series of highly accurate measurements of the Shapiro time-delay (laser ranging accurate to 1 cm) and interferometric astrometry (accurate to 0.1 picoradian), LATOR will measure gravitational deflection of light by the solar gravity with accuracy of 1 part in a billion, a factor 30,000 better than currently available. LATOR will perform series of highly-accurate tests of gravitation and cosmology...

6.10 Applications and Architectures for Wireless Sensor Networks

Session Organizer: Mitchell Lebold, Penn State University

6.1001 Reconfigurable Protocol Sensing for Space-based Applications

Clayton Okino, Ryan Mukai, Joshua Schoolcraft, Andrew Gray (Jet Propulsion Laboratory)

In this paper, we present sensing performance using an architecture for a reconfigurable protocol chip for space-based applications. We examine three common framing standards and present the sensing performance of these standards and their decorrelation statistics. We also examine the impact over lossy links. Finally, we describe a process flow for development of this sensor mechanism.

6.1002 Adaptive Sinkhole Detection on Wireless Ad Hoc Networks

Thanachai Thumthawatworn, Tapanan Yeophantong, Punthep Sirikriengkrai (Assumption University)

Detecting intrusions on wireless ad hoc network is one of the most challenging issues facing today's researchers. Its dynamic nature causes a number of difficulties in implementing its security features. In a highly dynamic ad hoc network, it is inefficient to learn behaviours of each node as nodes move in and out of the network frequently. This research introduces an approach for sinkhole countermeasure. Sinkholes are malicious nodes that do not relay the data to a destination, causing an availability problem to the network. We present a trust-based mechanism for adaptively defending against sinkhole attacks in an ad hoc system.

6.1003 Multiobjective Energy-aware Node Selection

Qiang Le(GaTech), Lance M. Kaplan(ARL), James H. McClellan(GaTech)

This work develops a resource management strategy for a wireless sensor network of bearings-only sensors. Specifically, the resource manager determines which nodes actively sense and communicate during each snapshot in order to achieve a tolerable level of geolocalization accuracy while attempting to maximize the effective lifetime of the network. Unlike other methods that use the total energy consumed for the given snapshot as an energy-based metric, a new energy-based (EB) metric can achieve load balancing of the nodes without resorting to computationally demanding non-myopic optimization. Simulation results show that EB provides longer lifetime than an existing geometry-based (GB) metric. We consider an adaptive transmission range control based upon the remaining battery level...

6.1004 Adaptive Working Schedule Modeling for Wireless Sensor Networks

Piyakul Tillapart, Tapanan Yeophantong, Thanachai Thumthawatworn, Teerawut Techachaicherdchoo, Umaporn Udomkul (Assumption University)

One major limitation of wireless sensor networks is that sensors have limited power. In general, sensors can operate over a period of time depending on assigned working schedule. For an application that requires collected data to construct a data model, sensors are ordered to periodically collect the data to ensure accuracy. However, the overall sensor's lifetime is reduced. To enhance the lifetime of a system, we propose a mechanism using statistical methods to adaptively construct a working schedule for each sensor node. The simulation results reveal that the system lifetime is increased while accuracy of data collected is maintained.

6.1005 An Introduction to IEEE STD 802.15.4

Jon T Adams (Freescale Semiconductor)

The concept of simple sensor nets, devices the size of ping-pong balls and sprinkled liberally on the ground, is compelling. Significant challenges have included cost, complexity, scaleability and power consumption. In 2003, the IEEE 802.15.4 standard was ratified which opened the door for single-chip radios with closely integrated sensors and processing and the ability to operate on a very low energy budget. This paper presents an overview of the standard`s functionality, performance and applicability.

6.1006 Using Wireless Sensor Technologies for Sense and Respond Logistic Applications

Mitchell Lebold, Brian Murphy, Karl Reichard (Penn State - Applied Research Lab.); Peter Sisa (RLW Inc.); Joe Gaines (Naval Supply Systems Command)

In today's competitive markets, the goal is to cut cost and reduce manning. This means simultaneously cutting spending on maintenance as well as ensuring equipment malfunctions do not occur. With reductions in maintenance schedules and the number technicians needed to perform required maintenance actions, a new health monitoring system needs developed that can not only diagnosis faults but can also place a request for parts and materials as well as schedule manpower needed to perform the repair action before the machine causes an unplanned failure. This paper discusses such an autonomous health monitoring system.

6.1007 Energy-Efficiency Analysis of Cluster-Based Routing Protocols in Wireless Sensor Networks

Guangyan Huang, Xiaowei Li, Jing He (Chinese Academy of Sciences)

This paper extends the conditions in terms of general algorithm complexity and general compressing ratio of data fusion, and network area with long distance in wireless sensor network. By using general models to evaluate them, the constant value of energy dissipation of 1-bit data fusion is an especial example, and the multi-hop scheme of existing protocols are not energy efficient, as well as some sensor nodes father from cluster head nodes than others worsen the death of nodes. The results of experiments reprove these discoveries. Furthermore, they provide guides for improving the above routing protocols to extent their application ranges.

Track 7: Spacecraft Avionics Systems & Technologies

Track Organizer: John Samson, Jr., Honeywell Inc.
Track Organizer: Scott Tyson, SES Consultants, Inc.

7.01 Onboard Processing Hardware Architectures and Interconnect Technologies

Session Organizer: Edward Prado, Honeywell Inc.
Session Organizer: Joseph Marshall, BAE SYSTEMS

7.0101 SpaceWire Protocol ID: What Does It Means To You?

Glenn Rakow, Richard Schnurr (NASA-GSFC); Steve Parkes (Univeristy of Dundee Space Technology Centre)

This paper addresses the lastest developments by the SpaceWire working group. This work is on the standarization track and will be described in a new standard, ECSS-E-50-11, that will complement the existing SpaceWire standard, ECSS-E-50-12A. This work details a new packet format that defines a Protocol ID and requires a logical address to be passed up to the end user. This feature will allow packets to be received in a standardized way and allow different protocols to be received by the same user in a standardized way.

7.0102 Advanced Optical Network

Steve Braun, Xuejun Michael Meng (L-3 PHOTONICS)

This paper describes an Advanced Dense Wavelength Division Multiplexing (DWDM) Optical Network developed by L-3 PHOTONICS. The network, configured as an amplified optical bus, carries traffic simultaneously in both directions, using multiple wavelengths. As a result, data distribution is of the form peer-to-multi-peer, it is protocol independent, and scalable. The network leverages the rapid growth in commercial optical technologies, including Wavelength Division Multiplexing (WDM), and when applied to military and commercial platforms such as aircraft, ships, unmanned and other vehicles, provides a cost effective, low weight, high speed, and high noise immune data distribution system.

7.0103 Ultrawideband Design Challenges for Wireless Chip-to-Chip Communications and Interconnects

Jamal Haque, Ed Prado (Honeywell Inc.); Hasari Celebi, Mustafa E. Sahin, Huseyin Arslan (University of South Florida); David P. Markell (Custom Manufacturing & Engineering Inc.)

A wireless interconnect alternative for traditional high pin count components is reviewed using high-speed ultrawideband (UWB) methods for chip to chip as well as off-board communications. UWB with its simple transceiver architecture, low power consumption, and high data rate within short ranges is shown to be viable solution for space borne as well as terrestrial applications.

7.0104 An Embedded Microcontroller for Spacecraft Applications

Joseph R. Marshall, Jeff Robertson (BAE Systems)

Originally conceived for fault tolerance control of its associated general purpose processor, the Embedded Microcontroller present in BAE Systems Power PCI ASIC has evolved into a processing workhorse finding applications spanning memory controllers, I/O processors as well as continuing to support the RAD750® processor. Development tools have also evolved from a simple assembler to a full development environment including compiler and simulator integrated with the PowerPC tools supporting the RAD750. Evolution of the EMC within the Power PCI Bridge, development of its support tools and some of its applications are discussed. Power and performance improvements are highlighted.

7.0105 Development of a High-Speed Multi-Channel Analog Data Acquisitioning Architecture

Linda M. Theis, Steven C. Persyn, Mark A. Johnson, Kelly D. Smith, Buddy J. Walls, Michael E. Epperly (Southwest Research Institute)

As the measurement techniques in the space science community rapidly evolve, the demand for multi-channeled, high-speed, radiation tolerant data acquisitioning systems gets increasingly higher. The high volume and resolution of data, and the complexity of the in-situ processing and analysis requirements, have triggered the need for faster, smaller, and easily reconfigurable designs. This paper presents a new design architecture

developed by Southwest Research Institute in response to this new demand. It also addresses the evolution of analog DSP data acquisition systems in general and emphasizes the advantages and tradeoffs between today's approaches versus older heritage methods.

7.02 Onboard Signal, Data, Command Processing and Data Handling Technologies

Session Organizer: Michael Lovellette, Naval Research Laboratory
Session Organizer: Stephen Ruggles, NASA Langley Research Center

7.03 Onboard Memory and Data Storage Technologies

Session Organizer: Craig Hafer, Aeroflex Colorado Springs
Session Organizer: Murty Polavarapu, BAE Systems

7.0301 Integration of Strontium-Bismuth-Tantalate Capacitors onto SOI Wafers

Karl F. Strauss (Jet Propulsion Laboratory); Bruce W. Black (Raytheon); Company); Vikram Joshi (IC Intelligence); Morifumo Ohno, Jiro Ida, Yoshiki Nagatomo (Oki Electric Industry, Japan)

The effect of integration of SBT Ferroelectric Capacitors onto Oki Fully Depleted SOI is presented. The paper explores the effect in terms of capacitor performance and transistor performance both pre- and post-irradiation to a level of 300 krads.

7.0302 Next Generation Radiation-Hardened SRAM for Space Applications

Craig Hafer, Jon Mabra, Duane Slocum (Aeroflex Colorado Springs); T.S. Kalkur (University of Colorado at Colorado Springs)

Aeroflex Colorado Springs has developed a monolithic 16M-bit SRAM radiation-hardened to greater than 100 krad(Si) total ionizing dose on TSMC's 0.18µm shallow trench isolation (STI) CMOS line using minimally invasive process intervention. Both single event latchup (SEL) and single event upset (SEU) due to charged particle strikes are mitigated by a combination of circuit design techniques, error detection and correction (EDAC), and enhanced layout design rules. The 16M-bit SRAM is SEL immune to greater than 105 MeV-cm2/mg. The SEU error rate is less than 2.9x10-16 errors/bit-day.

7.04 Reconfigurable Computing System Technologies

Session Organizer: Ian Troxel, University of Florida
Session Organizer: Jeremy Ramos, Honeywell DSES
Session Organizer: Russ Duren, Baylor University

7.0401 SEU Mitigation for Reconfigurable FPGAs

David R. Czajkowski, Praveen K. Samudrala, Manish P. Pagey (Space Micro, Inc.)

This paper discusses the application of Space Micro`s Time-Triple Modular Redundancy (TTMR™) and Hardened-Core (H-Core™) technologies for Xilinx Virtex-II FPGAs. TTMR is the application of time and spatial redundancy for mitigating Single Event Upsets (SEU). H-Core is an auxiliary rad-hard chip used for mitigating Single Event Functional Interrupts (SEFI). These technologies have been proven to perform excellently under radiation and are presently the driving force behind our powerful rad-hard computers built from COTS processors. We provide proton radiation test data confirming mitigated performance in Virtex II FPGA for SEUs and SEFIs.

7.0402 Techniques to Enable FPGA Based Reconfigurable Fault Tolerant Space Computing

Grant L. Smith, Lou de la Torre (Honeywell)

Reconfigurable computing using Field Programmable Gate Arrays (FPGAs) offer significant performance improvements over traditional space based processing solutions. A fault tolerant reconfigurable computing architecture that uses external triple modular redundancy (TMR) via a radiation-hardened ASIC provides the most robust approach to SEU and SEFI detection and mitigation. Honeywell has designed a TMR Voter ASIC with an integrated

FPGA configuration manager that can automatically reconfigure an upset FPGA upon TMR error detection. The reliability equations that apply to external TMR systems are reviewed and graphed. It is shown that automating and minimizing reconfiguration/resynchronization times enables high performance FPGA-based processors to provide...

7.0403 High-Performance, Dependable Multiprocessor

Jeremy Ramos, John R. Samson, Jr. David Lupia (Honeywell Defense and Space); Minesh Patel, Vikas Aggarwal (Tandel Systems, LLC); Rafi Some (Jet Propulsion Laboratory); Ian Troxel, Rajagopal Subramaniyan, Adam Jacobs, James Greco, Grzegorz Cieslewski, John Curreri, Michael Fischer, Eric Grobelny, Alan George (University of Florida)

With the ever increasing demand for higher bandwidth and processing capacity of today's space exploration, space science, and defense missions, the ability to efficiently apply commercial-off-the-shelf (COTS) processors for on-board With the ever increasing demand for higher bandwidth and processing capacity of today's space exploration, space science, and defense missions, the ability to efficiently apply commercial-off-the-shelf (COTS) processors for on-board computing is now a critical need. In response to this need, NASA's New Millennium Program office has commissioned the development of Dependable Multiprocessor (DM) technology for use in payload and robotic missions. To date, Honeywell has successfully demonstrated a TRL4...

7.0404 Hardware/software Interface for High-performance Space Computing with FPGA Coprocessors

James Greco, Grzegorz Cieslewski, Adam Jacobs, Ian A. Troxel, and Alan D. George (University of Florida)

Complex real-time signal and image processing applications require low-latency and high-performance hardware to achieve optimal performance. Building such a high-performance platform for space deployment is hampered by hostile environmental conditions and power constraints. This paper explores a framework that allows earth and space scientists to use FPGA resources through an abstraction layer. The performance of a SAR application, implemented with the framework, is shown to achieve a speedup of 19 when compared to a software solution. Projected speedups, for the same case study executing on the proposed flight system architecture, are several times better and also discussed.

7.0407 Design and Implementation of Double Precision Floating Point Division and Square Root on FPGAs

Abdel Ejnioui, Anuja J. Thakkar (University of Central Florida)

This paper presents the sequential and pipelined designs of a double precision floating point divider and square root unit. The pipelining of these units is based on unrolling of the iterations in low-radix digit recurrence algorithms. The implementations of these designs show that their performances are comparable to, and sometimes higher than, the performances of non-iterative designs based on high radix numbers. While the iterative divider and square root unit occupy less than 1% of an XC2V6000 FPGA chip, their pipelined counterparts can produce throughputs that reach the 100 MFLOPS mark by consuming a modest 8% of the chip area.

7.05 Mixed Signal and System-on-a-Chip Technologies

Session Organizer: Mark Martin, The Johns Hopkins University APL

Session Organizer: Nikolaos Paschalidis, The Johns Hopkins University APL

7.0501 Power Remote Input Output ASIC (PRIO)

Mark N. Martin, Kim Strohbehn, Wesley P. Millard, Richard C. Meitzler, Martin E. Fraeman and Stephen E. Jaskulek (The Johns Hopkins University)

The Power Remote I/O (PRIO) ASIC is a single chip, multi-channel monitoring device. The PRIO has internal buffers with externally programmable attenuation to allow the PRIO to safely monitor voltages in the range of -40V to +40V DC. The current monitoring is

accomplished with an external toroid pickup. The ASIC operates from a 5V supply and communicates with the spacecraft via an I2C interface.

7.0502 Radiation Tolerant Mixed Signal Microcontroller for Martian Surface Applications

Martin E. Fraeman, Richard C. Meitzler, Mark N. Martin, Wesley P. Millard, Joanna D. Mellert, Jessica N. Bowles-Martinez, Kim Strohbehn, David R. Roth (The John Hopkins University); Yanyi L. Wong (University of Maryland)

We are developing a radiation tolerant, mixed-signal microcontroller for applications exposed to the Martian surface thermal environment. The microcontroller includes a variety of digital and mixed signal peripherals. There is an on-chip scratchpad SRAM and EEPROM as well as an external memory bus. All memory interfaces implement single-bit error correction and two-bit error detection.

7.06 Miniaturization and Advanced Electronics Packaging for Satellites

Session Organizer: Andrew Shapiro, Jet Propulsion Laboratory, Caltech
Session Organizer: M. Ann Darrin, The Johns Hopkins University APL
Session Organizer: Raphael Some, Jet Propulsion Labs

7.0601 Reliability Assessment of COB Technology for Extreme Low Temperature Environment

Sharon Ling (The Johns Hopkins University)

This paper summarizes a comprehensive study conducted on the COB technology that will be used in the MSL motor controller electronics. An extensive test matrix is designed and developed, and thermal cycle tests (-125oC to +85oC) are conducted to identify the failure mechanisms in the extreme temperature environment on Mars. Relevant materials are tested to and beyond the -125oC limit for their properties and application feasibilities. Failures observed during the thermal cycle test, failure mechanism identifications, as well as test results will be presented in this paper.

7.0602 Electrical and Mechanical Characterization of Carbon Nanotube Filled Conductive Adhesive

Jing Li, Janet K. Lumpp (University of Kentucky)

Electronic assemblies rely heavily on soldering to attach components to the interconnect wiring on printed circuit boards and other types of substrates. In response to environmental legislation, the lead-tin alloys commonly used for soldering are being replaced with lead-free alloys and electrically conductive adhesives. Replacing the metal particles with carbon nanotubes in conductive adhesive compositions has the potential benefits of being lead free, low process temperature, corrosion resistant, high electrical conductivity, high mechanical strength and lightweight. Contact resistance, volume resistivity, high frequency performance, thermal conductivity and mechanical properties were measured and compared with metal filled adhesives and traditional solder paste.

7.0603 Embedded Resistors and Capacitors in Organic and Inorganic Substrates

R. David Gerke (Jet Propulsion Laboratory); Danielle Ator (University of Idaho)

Embedded resistors and capacitors were purchased from two technologies; organic PWB and inorganic low temperature co-fired ceramic (LTCC). Small groups of each substrate were exposed to four environmental tests and several characterization tests to evaluate their performance and reliability. Even though all passive components maintained electrical performance throughout environmental testing, differences between the two technologies were observed. Environmental testing was taken beyond manufacturers' reported testing, but generally not taken to failure. When possible, data was quantitatively compared to manufacturer's data.

7.07 Advanced Electronics for Robust Space Systems

Session Organizer: Andrzej Peczalski, Honeywell Advanced Sensor Technologies

7.0701 Radiation-tolerant Diffuse Infrared Optical Backplane Development

Richard C. Meitzler, Miriam A. Marwick, Wolfger Schneider (The Johns Hopkins University Applied Physics Laboratory)

We describe the development of a diffuse infrared optical backplane technology for small satellites. After an overview of the system architecture and previous work, we discuss the design and implementation of a radiation tolerant interface ASIC. This ASIC, which is fabricated in a silicon-on-sapphire process, contains test circuits for the interface between the photonic components (VCSEL and PiN photodiode) and the transceiver's digital logic. In addition, we describe further work towards the improvement of our system's range and the creation of a fully integrated digital node.

7.08 Fault Tolerance, Autonomy, and Evolvability in Spacecraft Avionics

Session Organizer: Didier Keymeulen, Jet Propulsion Laboratory, Caltech
Session Organizer: Tom Hoffman, Jet Propulsion Laboratory, Caltech

7.0801 Run-Time Behavior of Ardea: A Dynamically Reconfigurable Distributed Embedded Control Architecture

Osamah A. Rawashdeh, James E. Lumpp, Jr. (University of Kentucky).)

Ardea (Automatically Reconfigurable Distributed Embedded Architectures) is a framework for developing dependable embedded systems based on graphical software specification. Ardea supports many fault-tolerance techniques including graceful degradation, where alternate implementations of software modules can be defined to replace primary implementations as hardware and software failures occur. At run-time, Ardea uses a set of managers on each processing element and a central "system manager" to recognize and respond to faults. This paper discusses the Ardea approach, Ardea's run-time behavior, and ongoing work on a prototype implementation of Ardea for control of autonomous UAVs.

7.0802 Spaceflight Multi-Processors with Fault Tolerance and Connectivity Tuned from Sparse to Dense

Laurence E. LaForge, Jeffrey R. Moreland (The Right Stuff of Tahoe); M. Sami Fadali (University of Nevada, Reno)

We describe a novel generation of multi-processor architectures, with fault tolerance and connectivity tuned from sparse to dense. Multivariate feasible regions minimize channel cost and latency, and maximize throughput and fault tolerance. Key to optimal designs: software-automation of the mathematics of connectivity. We introduce a new theorem that explicates the structure of Hamming graphs, together with a new, efficient algorithm for recognizing and labeling Hamming graphs. Grid computing applications that benefit from tunable topologies include: i) design of multi-processors, coupled via vertical cavity surface emitting lasers (VCSELs); ii) auto-configuration of mobile ad hoc networks (MANETs) via digital radio-frequency channels.

7.0803 Design of a Novel Soft Error Mitigation Technique for Reconfigurable Architectures

Sajid Baloch, Tughrul Arslan (University of Edinburgh); Adrian Stoica (Jet Propulsion Laboratory)

Commercially off the shelf (COTS) available reconfigurable architectures are becoming popular for applications where high dependability, performance and low costs are mandatory constraints such as space applications. We present a unique SEE (single Event Effect) mitigation technique based upon Temporal Data Sampling and Weighted Voting for synchronous circuits and configuration bit storage for reconfigurable Architectures. The design technique addresses both conventional static SEUs (Single Event Upsets) and SETs (Single Event Transients) induced errors which result in data loss for reconfigurable architectures in space. The design technique not only eliminates all the single event upsets and single event transients but eliminates...

7.0804 Extreme Temperature Electronics Using a Reconfigurable Analog Array

Ricardo S. Zebulum, Didier Keymeulen, Ramesham Rejeshuni,Taher Daud, Adrian Stoica (Jet Propulsion Laboratory); Joseph Neff (SPAWAR)

Temperature and radiation tolerant electronics, as well as long life survivability are key capabilities required for future NASA missions. Current approaches to electronics for extreme environments focus on component level robustness and hardening. Compensation techniques such as bias cancellation circuitry have also been employed. However, current technology can only ensure very limited lifetime in extreme environments. Previous work presented a novel approach, based on evolvable hardware technology, which allows adaptive in-situ circuit redesign/reconfiguration during operation in extreme environments. This technology would complement material/device advancements and increase the mission capability to survive harsh environments. This work describes a new reconfigurable analog...

7.0805 Data Converters Performance at Extreme Temperatures

Rajeshuni Ramesham Nikil Kumar James Mao, Didier Keymeulen Ricardo S. Zebulum Adrian Stoica (Jet Propulsion Laboratory)

Space missions often require radiation and extreme-temperature hardened electronics to survive the harsh environments beyond earth's atmosphere. Traditional approaches to preserve electronics incorporate shielding, insulation and redundancy at the expense of power and weight. However, a novel way of bypassing these problems is the concept of evolutionary hardware. A reconfigurable device, consisting of several switches interconnected with analog/digital parts, is controlled by an evolutionary processor (EP). When the EP detects degradation in the circuit it sends signals to reconfigure the switches, thus forming a new circuit with the desired output. This concept has been developed since the mid-90s, but one...

7.0806 Tuning of MEMS devices using Evolutionary Computation and Open-Loop Frequency Response

Didier Keymeulen, Michael I. Ferguson, Luke Breuer, Chris Peay, Boris Oks (Jet Propulsion Laboratory); Yen-Cheng, Dennis Kim (UCLA); Eric MacDonald (University of Texas at El Paso); David Foor(Texas A&M University); Richard Terrile, Karl Yee (Jet Propulsion Laboratory)

We propose a tuning method for Micro-Electro-Mechanical Systems (MEMS) gyroscopes based on evolutionary computation that has the capacity to efficiently increase the sensitivity of MEMS gyroscopes through tuning and, furthermore, to find the optimally tuned configuration for this state of increased sensitivity. We present the results of an experiment to determine the speed and efficiency of an evolutionary algorithm applied to electrostatic tuning of MEMS micro gyros. The MEMS gyro used in this experiment is a pyrex post resonator gyro (PRG) in a closed-loop control system. A measure of the quality of tuning is given by the difference in resonant...

7.09 Electronics for Extreme Environments

Session Organizer: Elizabeth Kolawa, Jet Propulsion Laboratory, Caltech
Session Organizer: Mohammad Mojarradi, Jet Propulsion Laboratory, Caltech

7.0901 Design for A/D Converter Reliability for Low Temperature Applications

Yuan Chen, Travis Johnson, Mohammad Mojaradi, Scott Cozy, Elizabeth Kolawa(Jet Propulsion Laboratory); Lynett Westergard, Curtis Billman(AMI)

We present a design for reliability approach on Analog to Digital converters for low temperature applications. Parametric degradation, including drain saturation and linear currents, threshold voltage, transconductance and drain conductance, have been characterized to translate the hot carrier aging impact on the circuits under low temperatures. Both substrate current profile and operating temperature profile have been taken into consideration to determine the most applicable transistor size to be used in the A/D converter and to ensure the required A/D converter reliability for low temperature applications.

7.0902 Solder Joint Fatigue Study Under Low Temperature Martian Conditions

Carissa Debra Tudryn (Jet Propulsion Laboratory)

Electronics, without heater power will need to survive mean surface temperatures of -120C to +20C for on Mars and an operational temperature up to 85C. Thermally induced fatigue is a concern since these electronics will need to survive 2010 cycles from -120C to +85C. The solder joint reliability of connectors with tin-lead finish and In80Pb15Ag5 solder on a PWB was investigated. Leads failed on a PWB with a silicone coating. SEM analysis revealed crack initiation at the lead finish. Another failure region was composed of several intermetallic compounds with intermetallic embrittlement as a failure mode.

7.0903 Star Tracker Focal Plane Evaluation for the JIMO Mission

Sergei Jerebets(Jet Propulsion Laboratory)

Survival and functionality of an imager and its radiation tolerance will be among the key criteria in the star tracker focal plane sensor selection for the JIMO mission. Despite attractive current CCD sensors performance characteristics, they will fall short in the severe radiation environment of the Jovian system. Further progress in CMOS technology allows contemporary APS to become an attractive candidate for space applications which are facing harsh radiation environment. At JPL, an extensive study has been initiated to understand available visible imager technologies such as CCD, CID, and APS in applications for radiation-tolerant star trackers.

7.0904 Model-Based Design Tools for Extending COTS Components to Extreme Environments

H. A. Mantooth, A. Levy, A. M. Francis (Lynguent); E. S. Cilio and A. B. Lostetter (Arkansas Power Electronics International)

Model-based design (MBD) tools to predict the performance and life of commercial-off-the-shelf (COTS) components and COTS-based systems outside of their rated temperature range are described. These tools are important in providing the means to quantify the reliability and lifetime of COTS components and COTS-based systems and provide a trade structure for the assessment of competing technologies. These novel modeling and design tools will provide a means of integrating disparate models and allow agile evolution of models. MBD tools will enable lower-cost system development and cost versus lifetime assessment, shorten development time, and extend proven technology to broader applications.

7.0905 Extreme Temperature/Radiation Tolerant Crystal Oscillator for High Reliability Space Applications

Kouros Sariri (Frequency Management International)

Frequency Management International is developing a practical solution for extreme temperature and radiation tolerant, compact radio frequency clock source (RTXO). Offering compelling features such as surface mounting, scalable configuration and miniature footprint.RTXO satisfies the critical requirements of NASA space programs such as Mars Science Laboratory (MSL), MER and future missions to Moon at both system and subsystem level with operating temperatures in the -180˚C to +120˚C. It also addresses the requirements of the extreme high temperature RTXO that could be utilized for the missions to Venus and other extreme environment space systems with highest operating temperature range to 460˚C.

7.0906 Ultra-Lightweight, High Efficiency SiC Based Power Electronic Converters for Extreme Environments

Sharmila Mounce, Brice McPherson, Roberto Schupbach, and Alexander Lostetter (Arkansas Power Electronics International, Inc.)

Silicon-carbide (SiC) semiconductor devices have numerous potential advantages over their conventional silicon counterparts (i.e. higher switching frequencies, lower switching losses, higher temperature of operation, higher blocking voltages, higher thermal conductivity, radiation hardness, etc.). These advantages have sparked the birth of a new generation of power converters, distinguishing themselves from their ancestors with a higher efficiency and operating frequency, resulting in a marked increase in power density

and a considerable reduction in weight. This paper explores the feasibility of developing a highly efficient, ultra-lightweight SiC based DC/DC converter, including the electrical design philosophy, high-temperature packaging approaches, high-temperature testing of several key...

7.0907 SiC Devices for Converter and Motor Drive Applications at Extreme Temperatures

Michael S. Mazzola, Robin Kelley, Janna Casady (SemiSouth Laboratories, Inc.); Cai Wang, Yi Liu, Wayne Johnson (Auburn University); Volodymyr Bondarenko (Mississippi State University)

The normally-off silicon carbide power JFET can perform the role of switch, rectifier, or switch with anti-parallel rectifier. This innovative feature eliminates the need to qualify a separate diode for extreme temperature environments. The VJFET reported here has demonstrated feasibility of at least a 500-h life at 500ºC. This paper also demonstrates a simple half-bridge variable speed motor drive that is free of discrete pn-junction or Schottky barrier rectifiers and is simple to control with pulse width modulation because it does not need a high-temperature high-side gate driver. Extending the approach to a full-bridge or a six-pulse bridge is straightforward.

7.0908 Low Temperature Performance of COTS Electronic Components for Martian Surface Applications

Yogesh Tugnawat and William Kuhn (Kansas State University)

Commercial-off-the-shelf (COTS) components were tested over the Martian temperature range for their use in a MARS proximity microtransceiver development project. These COTS components include off-chip IF filters, off-chip TCXOs, and on-chip components such as MOSFETS, resistors and capacitors. The on-chip components are from a rad-hard Silicon-on-Sapphire (SOS) IC process. Novel methods were developed to reliably measure component characteristics at cryogenic temperatures. Measurements were then taken from 25°C to -120°C in steps of 20oC. The results achieved look promising and provide useful information for analog circuit designers developing circuitry for extreme low temperature ranges.

7.10 Spacecraft Guidance, Navigation, and Control Technologies

Session Organizer: Anhtuan Ngo, U.S. Air Force Research Laboratory
Session Organizer: James Luecke, L-3 Communications - IEC
Session Organizer: Michael Oppenheimer, AFRL/VACA

7.1001 Resources Minimization in the Satellite Navigation Process

Mohamed A. Zayan (The Egyptian Satellites Company (Nilesat))

Minimizing the resources and observation data, which are required to navigate the satellite motion, will make the navigation process more reliable, and robust. In this paper, the methods of orbit determination and estimation will be analyzed from the point of view of the recourses and observation tracking available. The paper will make a comparison among possible solutions using combinations of the available tracking data. The different combinations of the tracking data will be analyzed and optimized to define and state the minimum possible data that should be sufficient to handle the problem of orbit determination.

7.1002 Concept of an Algorithm to Determine the Signal Delay Time for Telepresence Space Applications

Enrico Stoll, Jürgen Letschnik, Ulrich Walter (Technische Universität München); Carsten Preusche, Gerd Hirzinger (German Aerospace Center)

The vision of a space robot as an extended arm of the human operator on ground is a key component for on-orbit robotic service missions. This concept of telepresence requires a high-quality sensor feedback from the space environment to the operator including stereo video and force-feedback. For the force feedback channel the knowledge of the signal delay time during operation is an important factor. The signal delay time varies according to the distance between the spacecraft and the ground station. This paper proposes a method for deriving the required signal delay from the Doppler frequency shift.

7.1003 Satellite Orbits Guidance Using State Space Neural Network

Mohamed A. Zayan (The Egyptian Satellites Company (Nilesat))

This paper develops a State-Space Neural Network (SSNN) to predict the satellite thruster force and control osculating orbital elements during maneuvers. Neural Predictive Control (NPC) is basically a type of Model-Based Predictive Control, where the model for predictions is a neural network. Incorporating neural-network models in Model Based Predictive Control (MBPC) algorithms providing a NPC. The neural network for obtaining the predictions in the MBPC scheme is called State-Space Neural Network (SSNN). State-space candidate models, which are likely to need less arguments than input-output models, this is clearly an advantage when small data sets only are available.

7.1004 Control of an Unstable, Nonminimum Phase Hypersonic Vehicle Model

Michael W. Oppenheimer and David B. Doman (Air Force Research Laboratory)

In this work, a control law for an unstable, nonminimum phase model of a hypersonic vehicle is developed. Due to the locations of the plant zeros and poles, there is a limited range of feedback gain that results in a stable system. Direct cancellation of the right-half plane zero with an unstable pole in the controller is not an option. The controller developed here differs from standard dynamic inversion in that it does not cancel the right-half plane zero with a pole, instead, it retains right-half plane zeros and uses an additional feedback loop to stabilize the zero dynamics.

7.1007 Application of 2D Differential Geometric Guidance to Tactical Missile Interception

Chaoyong Li,Wuxing Jing(Harbin Institute of Technology), Hui Wang,Zhiguo Qi(THe 8th Insitute of Shanghai Academy of Spaceflight Technology)

The application of 2D differential geometric(DG)guidance law to a realistic tactical missile interception scenario is investigated. In particular, the capture capability and interception performance of the law are analyzed. The classical differential geometry theory is utilized firstly to transform the DG guidance curvature command from arc-length system to the time domain. Then, an algorithm for the angle of attack command is derived to form the DG guidance law. Finally, a new necessary initial condition is deduced to guarantee capture of high speed targets. Simulations results indicate the proposed guidance law perform better than PN guidance law.

7.1008 Iterative Solution to Three-dimensional Differential Geometric Guidance Problem

Chaoyong Li, Wuxing Jing (Harbin Institute of Technology); Hui Wang, Zhiguo Qi (The 8th Institute of Shanghai Academy of Spaceflight Technology)

The application of three-dimensional (3D) differential geometric (DG) guidance commands is investigated. Also, the iterative solution to DG guidance system is studied. Classical differential geometry theory is utilized firstly to transform DG guidance commands from an arc-length system to the time domain. Secondly, the Newton iterative algorithm is introduced to derive an iterative solution to facilitate computation of angle-of-attack and side slide angle command, which are designed to be output of 3D DG guidance law. Finally, the new necessary initial condition is developed to guarantee capture of high speed targets. Simulation results indicate DG guidance law performs better than PNG.

7.11 Advanced Spacecraft and Mission Concepts

Session Organizer: James Lyke, Space Vehicles Directorate
Session Organizer: William Jackson, SpaceDev

7.1101 Aero-WAVE: A W-band Preliminary Test using HAP

A. Jebril, M. Lucente, T. Rossi, M. Ruggieri (University of Rome-Tor Vergata), L. Zuliani (Italian Space Agency)

In this paper, the Aero-WAVE mission is presented as a preliminary test to provide the necessary measures leading to the development of the primary mission into GEO orbit. Aero-WAVE is a scientific payload that operates in W-band. It will be embarked onboard the M-55 Geophysica High Altitude Platform (HAP) in order to perform a first test of the

channel behavior at an altitude of about 20 km. These measurements and the resulting data provided throughout the Aero-WAVE mission will give good indications of the channel behavior at different weather conditions and at different locations within the GEO-WAVE coverage.

7.1102 Minimal Fuel Consumption of Electric Propulsion Space Vehicles for Deep Space Exploration

Bandi Bharat Kumar Reddy, Albert C. Esterline, Abdollah Homaifar(Dept of Electrical and Computer Engineering at NC A&T SU)

The objective of this research is to develop a methodology to find a near optimal control strategy for the JIMO spacecraft for high fuel efficiency while traversing between two points in space represented by longitude, latitude and radius. The control profiles of the spacecraft are thrust ON (Thrusting), Thrust OFF (Coasting), the thrust angle of attack and the roll angle of the spacecraft. The trajectory being investigated is for the heliocentric case. Micro Genetic Algorithms (GA) with the concept of Elitism is used to determine this near optimal control strategy...

7.1103 Multi-Processors by the Numbers: Mathematical Foundations of Spaceflight Grid Computing

Laurence E. LaForge, James W. G. Turner (The Right Stuff of Tahoe)

Addressing a general audience, we provide an example-and-diagram description of how the mathematics of connectivity elucidates predictive insights about multi-processor architectures. Space missions, can (and should) benefit at a level where avionics designers have the most leverage. Combining classical results with fresh research unveils new methods for maximizing fault tolerance and throughput, and for minimizing latency and cost. The payoff: platforms that optimize multi-processors spanning hundreds – or even thousands – of nodes. Enablers for grids of spaceborn processors include: i) tunable multi-processor topologies; ii) the vertical cavity surface emitting laser (VCSEL); iii) multi-processor partitioning of flight software.

7.12 Large Space-Based Sensor Platforms

Session Organizer: Gerard Genello, Air Force Research Laboratory

Track 8: Spacecraft & Launch Vehicle Systems & Technologies

Track Organizer: Erik Nilsen, Jet Propulsion Laboratory, Caltech
Track Organizer: Rex Kiziah, Air Force Research Laboratory
Track Organizer: Ruth Moser, AFRL/VSSL

8.01 Innovative Satellite Technologies and Architectures

Session Organizer: Timothy Lawrence, USAFA

8.0101 A Micro High-Temperature Superconductor System: Fabrication and Operation

Eunjeong Lee, Bongsu Kim, Junseok Ko, Chi Young Song, Seong-Jin Kim, Sangkwon Jeong, and Seung S. Lee (Korea Advanced Institute of Science and Technology)

This paper presents the development of an integrated micro high-temperature superconductor system for energy storage and attitude control of three-axis stabilized nano satellites. The micro high-temperature superconductor system consists of a flywheel/rotor, motor/generator, and motor electronics. The stator for motor/generator has been fabricated by micro fabrication technology. An alternative stator has been fabricated by cutting a 50 micron-thick copper film for comparison. It has been observed that the micro fabricated stator can make the flywheel rotate at a constant velocity of up to 12,000 rpm. Experiments show that the micro fabricated stator can significantly reduce the motor/generator losses.

8.02 Transformational Communications Enabling Technologies

Session Organizer: Ruth Moser, AFRL/VSSL

8.0201 Image Based Acquisition and Tracking for Multi-Access Laser Communications

Charles W. Hindman, Seth L. Lacy, Nicole Hatten (Air Force Research Laboratory)

Long-range laser communications links offer many potential advantages to satellite communications systems. However, the establishment of a laser communications link can be very difficult and time consuming. Most of the difficulty lies in the first step of actually painting the partner terminal with a laser spot or detecting said spot due to large uncertainties, terminal vibrations and jitter, bright optical backgrounds and clutter. A detailed physical and statistical model of this first detection process has been developed and verified against computer simulations using representative background images to ensure the success of this critical first step in the acquisition process.

8.0202 Atmospheric and Platform Jitter Effects on Laser Acquisition Patterns

Charles W. Hindman, Brian S. Engberg (Air Force Research Laboratory)

Several applications exist that require the acquisition of a distant target by scanning a laser beam over some uncertainty cone. The parameters of this scan can be adjusted to provide an acceptable intensity pattern within the uncertainty region. However, disturbances in the form of uncompensated platform jitter, and atmospheric scintillation combine to distort the desired pattern in the far field. A detailed simulation of these processes is developed and used as the basis for a trade study to show how to optimize the search parameters and maximize the probability of detection for a given set of disturbance inputs.

8.03 Innovative Structures and Materials for Space and Launch Vehicle Systems

Session Organizer: Douglas Campbell, Composite Technology Development

Session Organizer: Lee Peterson, University of Colorado

8.0301 Development of a Novel, Passively Deployed Roll-Out Solar Array

Douglas Campbell, Rory Barrett, Mark S. Lake, Larry Adams, Erik Abrahmson (Composite Technology Development), Mark R. Scherbarth, Jeffry S. Welsh (Air Force Research Laboratory);/VSSV), Gregg Freebury, Neil Beidleman (Idea Inc.), and Jamie Abbot (JLA Technologies)

Current large, solar array systems are limited to less than 15 kW of total power, at roughly 50 W/kg. The Roll Out and Passively Deployed Array (RAPDAR) design will demonstrate the feasibility of 50 kW, 250 W/kg-class solar array systems through an innovative design

that takes full advantage of the latest advances in thin-film photovoltaic and TEMBO® Elastic Memory Composite (EMC) deployment technologies. The present paper presents analysis and test correlation of several aspects of the RAPDAR solar array system including the concept of passive deployment and EMC longeron performance.

8.04 Satellite Dynamic Systems and Controls

Session Organizer: Daniel Scharf, Jet Propulsion Laboratory, Caltech
Session Organizer: Seth Lacy, Air Force Research Laboratory

8.0401 Spacecraft Inertia Estimation Via Constrained Least Squares

Jason A. Keim, A. Behcet Acikmese, Joel F. Shields (Jet Propulsion Laboratory)

This paper presents a new formulation for spacecraft inertia estimation from data. Specifically, the inertia estimation problem is formulated as a constrained least squares minimization problem with explicit bounds on the inertia matrix incorporated as linear matrix inequalities. The resulting minimization problem is a semidefinite optimization problem that can be solved efficiently with guaranteed convergence to the global optimum by available algorithms. This method is applied to data collected from the Formation Control Testbed. The results show that the constrained least squares approach produces more accurate estimates of the inertia matrix than standard unconstrained least squares estimation methods.

8.0402 Parallel Estimation and Control Architectures for Deep-Space Formation Flying Spacecraft

Roy S. Smith (University of California, Santa Barbara); Fred Y. Hadaegh (Jet Propulsion Laboratory)

Precisely controlled spacecraft formations can implement extremely high performance science instruments, including optical imagers. Extreme precision and a significant level of autonomy are required; each spacecraft must base its actions on its estimates of the positions of the other spacecraft. Using standard Kalman filter-based designs can lead to unanticipated and potentially destabilizing dynamics. The communication amongst the spacecraft can be designed to ameliorate the effect of these dynamics. Results relating the topology of the communication network to the closed-loop dynamics of the formation are presented. The consequences for the design of the control, communication and coordination are discussed.

8.0403 Positioning of Satellites Through Continuous Firing

Valerio Nicolai, Marina Ruggieri, Pietro Salvini (University of Rome "Tor Vergata"" - Italy)

Orbital pushing is going to be an important task to plan, due to the increase of shared or piggyback launches that imply the release of small satellites in orbits different from the final one. Orbital reconfigurations could be considered an added value if they can be performed avoiding a considerable consumption of fuel that is not renewable. To this respect ion-engines could help because they are characterized by a high reliability and a particular low fuel consumption. The paper explores the advantage to make use of a continuous firing technique by an ion-engine to change the orbital parameters.

8.0404 A Modified Minimal Controller Synthesis for Satellite Attitude Control

Thawar T Arif (Al-Isra Private University, Jordan)

The Minimal Controller Synthesis (MCS), is an extension of hyperstable Model Reference Adaptive Control (MRAC) algorithm. The aim of MCS is to achieve excellent closed-loop control despite the presence of plant parameter variations, external disturbances, dynamic coupling within the plant and plant nonlinearities. A modification on the MCS algorithm is proposed in this paper to highly enhance the robustness of the controlled system against disturbances. The Infra-Red Astronomical Satellite (IRAS) attitude control system was simulated using the proposed algorithm. The simulation results were excellent compared with other algorithms already used for controlling the attitude control system of the IRAS satellite.

8.0405 Robustness of an Optimized Fuzzy Logic Controller to Plant Variations

Hossein Zadeh (RMIT University); Lorenz Drack, John Wharington (Defence Science Technology Organization)

The application of a stochastic optimizer to the problem of the control of a highly flexible space structure, and its robustness, is described. The optimized fuzzy logic controller is used to perform a certain maneuver. A model of the flexible space structure was developed in a rigid multi-body dynamics software package called Odessa and was used as a basis for deriving a number of other simulation models, that have physical properties deviating from those of the ideal model. These simulations show the fuzzy logic controller to be remarkably robust.

8.05 Responsive Space Technologies

Session Organizer: Peter Wegner, AFRL/VS

8.0501 Low-Cost Propellant Launch to Earth Orbit from a Tethered Balloon

Brian H. Wilcox (Jet Propulsion Laboratory)

This paper describes a possible means for launching thousands of tons of propellant per year into LEO at a cost 15 to 30 times less than the current launch cost per kilogram. The basic idea is to mass-produce very simple, small and relatively low-performance rockets that are able to reach orbit because they are launched from a tethered balloon above >95% of the atmosphere, where the drag losses even on a small rocket are acceptable, and because they can be launched nearly horizontally with very simple guidance based largely on spin-stabilization.

8.06 Power Subsystem Architectures and Technologies

Session Organizer: John Merrill, Air Force Research Labs/VSSV

8.0601 Uniform Voltage Distribution Control for Series-Input Parallel-Output, Connected Converters

Kasemsan Siri, Michael Willhoff, Calvin Truong, and Kenneth A. Conner (The Aerospace Corporation)

This paper extends the application of current-mode, shared-bus converters to power system architectures configured as Series-Input, Parallel-Output (SIPO). By employing a SIPO interconnect method, current-mode commercial-off-the-shelf (COTS) dc-dc converters can transform higher input voltages into low output voltages, provide flexible options for power system expansion, and preserve system efficiencies equal to that obtained from standalone converters. However, without proper control, converter component mismatches make the input voltage non-uniformly distributed. System reliability suffers as a result of thermal overstress. Conversely, robust system stability and uniform input voltage distribution among series-connected converters is realized through input voltage distribution control.

8.0602 A Distributed Design Architecture for Li-ion Battery: Integration of COTS ICs, ?Cs and CAN Bus

Carlo Del Vecchio Blanco (University of Naples 'Federico II'DISIS), Marco D'Errico (Second University of Naples); Alessandro Conticchio (University of Naples 'Federico II'DISIS)

In the proposed paper the modular and autonomous architecture concepts are deeply analyzed and applied to the design of an innovative Li-ion modular battery as test case. The single module integrates 6 terrestrial Li-Ion cells, the charge/discharge electronics and PIC microcontroller that supervises battery health and provides monitoring to an on-board computer. A Controller Area Network (CAN) bus connection is implemented in several battery modules and the communication protocol has been developed and tested...

8.0603 A PV Power Generation System for Missions to Mercury

Michele Macellari, Raffaele Russo, Luigi Schirone (Università degli Studi di Roma La Sapienza)

A special architecture for photovoltaic generation of electricity has been studied for a mission to Mercury. This paper deals with solar panel design primary concerns, with regards to the harsh Hermian thermal environment and to the need for great amounts of power for solar electric propulsion at 1 A.U.. A novel concept of a combined system of

photovoltaic generators together with Fresnel lens solar concentrators will be presented as a possible solution to the different power demands of the whole mission.

8.07 Technologies for Lunar and Planetary Exploration

Session Organizer: Jeff Estefan, Jet Propulsion Laboratory, Caltech

8.08 Nuclear Systems for Space Exploration

Session Organizer: Jacklyn Green, Jet Propulsion Laboratory, Caltech

8.0801 International Intellectual Property Rights for Aerospace Nuclear Power Technologies

Hulsey (Intellectual Property Lawyers.)

Increasing the potential for commercial opportunities related to the national space exploration vision requires providing incentives for entrepreneurial investment in space and assuring that appropriate property rights exist for those who seek to develop space resources and infrastructure. These incentives, however, will vary according the specific technology at issue and the related assets affecting commercial opportunities for the technology. Technology licensing and other strategies permit proactively expanding the range of commercialization alternatives for different technologies. Knowledge and experience with patent and technology intellectual property matters assist in analyzing commercial opportunities that promote commercial activities in support of supporting the national...

8.0802 Exploring Europa with an RPS-Powered Orbiter Spacecraft

Robert D. Abelson, Thomas R. Spilker, James H. Shirley, Jacklyn R. Green, William B. Smythe (Jet Propulsion Laboratory)

This paper describes a conceptual flagship-class Europa orbiter concept that was assumed to launch as early as 2012, arriving at Europa 8 years later using inner solar system gravity assists to reach Jupiter. Large heliocentric distances, high power levels required, and especially the harsh Jovian radiation environment drove the selection of RTGs for all onboard electrical power. Mass and architecture trades were performed using different spacecraft trajectories, launch vehicle types, radioisotope power systems, and mission durations. The study shows that new mission constraints allow a scientifically compelling Europa orbiter mission that might also deliver a Europa lander.

8.0803 Development of Segmented Thermoelectric Multicouple Converter Technology

Jean-Pierre Fleurial, Kenneth Johnson, Jack Mondt, Jeff Sakamoto, Jeff Snyder, Chen-Kuo Huang, Richard Blair, Gerhard Stapfer, Thierry Caillat (Jet Propulsion Laboratory), William Determan, Patrick Frye (Pratt & Whitney); Ben Heshmatpour, Michael Brooks (Teledyne Energy Systems, Inc.), and Karen Tuttle (NASA GRC)

The Jet Propulsion Laboratory (JPL), Pratt & Whitney Rocketdyne, and Teledyne Energy Systems, Inc. have teamed together under JPL leadership to develop the next generation of advanced thermoelectric space reactor power conversion systems. The technologies required for such a power system include liquid metal cooled reactors with outlet temperatures ranging from 1125 K up to 1325 K and segmented thermoelectric multicouple converter (STMC) arrays which can achieve greater than 8 percent system efficiency. The performance of the selected high temperature TE materials and initial thermal, electrical and mechanical test results on several STMC demonstration devices are reported.

8.09 Reconfigurable Space Systems and Space Assembly

Session Organizer: Andrew Zimdars, Advanced Technology Center, Lockheed Martin Space

8.0901 Probability Based Partial Triple Modular Redundancy Technique for Reconfigurable Architectures

Sajid Baloch, Tughrul Arslan (University of Edinburgh); Adrian Stoica (Jet Propulsion Laboratory)

This paper represents a design technique for hardening combinational circuits mapped onto any reconfigurable architecture. An effective and simple algorithm for signal

probabilities has been used to detect SEU sensitive gates for a given combinational circuit. The circuit can be hardened against radiation effects by applying triple modular redundancy (TMR) technique to only these sensitive gates. PTMR is tested against different circuits to prove its efficacy. With a small loss of SEU immunity, the proposed PTMR scheme can greatly reduce the area overhead as compare to TMR technique. PTMR scheme along with reconfiguration feature of FPGAs can result into a...

8.0902 Alignment, Capture and Mate (ACM) Docking System Development for Space Exploration

John Ringelberg (Lockheed Martin)

This paper describes the origin and development of the Alignment, Capture and Mate (ACM) docking system that was under development by Lockheed Martin Space Systems Company (LMSSC) in Denver, Colorado, prior to program cancellation in November 2006. The ACM is an androgynous, automated docking system with embedded final approach guidance sensors developed to support in-space assembly operations for the NASA Space Exploration initiative. The concept for the docking system is based on lessons learned from other docking systems, and from a common sense approach to providing a common, reliable system for assembling future elements of the NASA Space Exploration vision.

8.0903 Space-Based Assembly with Symbolic and Continuous Planning Experts

Ella Atkins, Gina Moylan, Aaron Hoskins (University of Maryland)

When considering the necessary role automation must play in future space missions and endeavors, it is important to study basic scenarios that further our understanding of the challenges we must overcome to meet such objectives. We believe some of these challenges lie in the inherent disconnect between the planning of tasks and the development of the continuous trajectories that must be followed to accomplish these tasks. By integrating optimal task planning with specialized astrodynamics “experts” for optimal orbit transfer and proximity docking operations, we show that a trajectory planning library can be developed that is both capable and efficient.

8.10 Autonomous Science Systems

Session Organizer: Rebecca Castano, Jet Propulsion Laboratory, Caltech

8.1001 Onboard detection of jarosite minerals with applications to Mars

Benjamin Bornstein, Rebecca Castano (Jet Propulsion Laboratory); Martha S. Gilmore, Matthew Merrill, James P. Greenwood (Wesleyan University)

We have developed a highly accurate Support Vector Machine (SVM) based detector capable of identifying jarosite in the visible/NIR (350–2500 nm) spectra of both laboratory specimens and rocks in Mars analogue field environments. We used our generative model to create linear mixtures of end-member library spectra to train the SVM. We validated the detector on museum quality laboratory samples (97% accuracy) and field rock samples (both 88% accuracy). In the interest of technology infusion, the detector has been integrated into the CLARAty autonomous mobile robotics software architecture.

8.1002 Opportunistic Rover Science

Rebecca Castano, Tara Estlin, Daniel Gaines, Andres Castano, Caroline Chouinard, Ben Bornstein, Robert C. Anderson, Steve Chien, Alex Fukunaga, and Michele Judd (Jet Propulsion Laboratory)

The goal of the Onboard Autonomous Science Investigation System (OASIS) project at NASA`s Jet Propulsion Laboratory (JPL) is to evaluate, and autonomously act upon, science data gathered by in-situ spacecraft, such as planetary landers and rovers.

8.1004 Near-Optimal Terrain Collision Avoidance Trajectories Using Elevation Maps

Seyyed M. Malaek, Alireza Abbasi (Sharif University of Technology)

The main attempt of the paper is to present a new methodology to model a generic low-level flight close to terrain, which guarantees terrain collision avoidance. This method uses satellite elevation maps to generate so called ‘Quad-tree forms’, which is used to find the optimal trajectory for low-level flights. The novelty of this approach, the ‘cost map’, lies in

the integration of aircraft dynamics into the digital map. This procedure results in some near-optimal trajectories with respect to aircraft dynamics that can be used for minimization of flight path together with pilot effort.

8.11 Technology Investment and Infusion

Session Organizer: David Tralli, Jet Propulsion Laboratory, Caltech
Session Organizer: Steven Cornford, Jet Propulsion Laboratory, Caltech

8.1101 Rapid Development of an Event Tree Modeling Tool Using COTS Software

Dev K. Sen, Justin C. Banks, Gaspare Maggio (SAIC), Jan Railsback (NASA)

TThis paper introduces a simple and powerful event tree modeling tool called EC Tree, which was developed using Microsoft Excel and Visual Basic. The tool enables the rapid construction of event trees of any complexity through easy-to-use templates, menu items, and shortcut keys. EC Tree was developed to facilitate the rapid generation of event trees for application to event based risk analyses, specifically for use in NASA's IM&S (Integrated Modeling and Simulation) Team. This paper describes EC Tree, its functionality, and the development process employed, specifically focusing on the process of rapid prototyping, programming, testing, and software release used.

8.1102 Infusing Software Assurance Research Techniques into Use

Thomas Pressburger (NASA Ames); Ben Di Vito (NASA Langley); Martin S. Feather (Jet Propulsion Laboratory); Michael Hinchey (NASA Goddard Space Flight Center); Lawrence Markosian ((QSS Group, Inc.); Luis C. Trevino (2L Research Corp.)

Research in the software engineering community is yielding techniques that encompass processes, methods and tools. This paper discusses obstacles that impedes the infusion of such techniques into software development practice, and describes an ongoing effort conducted by a software engineering research infusion team established by NASA's Software Engineering Initiative to overcome these obstacles. This effort has demonstrated an inexpensive and effective process for brokering matches between software engineering researchers and practitioners that can be incorporated into NASA's overall strategies for infusion of software engineering research products, and specifically for research products that can improve software safety and mission assurance.

8.1103 Planning a Large-Scale Progression of R&D a Pilot Study in the Aerospace Domain

Andrew Shapiro, Steven L. Cornford, Martin S. Feather (Jet Propulsion Laboratory);), George Price, Yuri O. Gawdiak (NASA HQ), Wendell R. Ricks (NASA Langley)

We report on a pilot study to gauge the suitability of adopting a lifecycle risk management decision-support tool to large-scale planning of a progression of research and development efforts in the Aerospace domain. The purpose of the study was to assess feasibility and utility, and to prototype adaptations to the approach as and when such adaptations were found to be needed. Overall it also pointed to several possible avenues to scale-up the approach, together with some remaining key problems.

Track 9: Air Vehicle Systems and Technologies

Track Organizer: Thomas Coleman, Raytheon

9.01 Aircraft Systems & Avionics

Session Organizer: Kelly Latimer, 418th Flight Test Squadron

9.0101 Autonomous Aerial Refueling Based on the Tanker Reference Frame

Steve Ross, Brian Kish (USAF Test Pilot School)

An aircraft formation autopilot is designed for flight test to demonstrate autonomous aerial refueling. The controller requirements are stated, and models for the lead and wing aircraft are outlined and stabilized. Control laws are developed for the model, and four frames of reference are investigated for optimal control. Results from simulations of the controller are presented and assessed. Results are presented from a limited flight test investigation conducted with a formation of an Air Force C-12 and a variable stability Learjet LJ-25, flown by the controller. Fully autonomous aerial refueling maneuvers were successfully demonstrated in both level and turning flight.

9.0102 An on-board inverter controlled by the waveform switching technique

Michele Macellari, Umberto Grasselli, Luigi Schirone (Università di Roma "La Sapienza")

This work discusses operating principles and performance of a 400Hz sine-wave inverter intended for aerospace applications. Its operation is controlled in PWM on the basis of the "waveform switching" technique. According to this fully-digital design approach, digitised sinewaves are stored in a solid-state memory; a control circuit cyclically reads the waveform samples and correspondingly sets duty cycle for every transistor in output bridge. Amplitude control is provided by changing the digitised waveform to be reproduced in output, by means of a specific feedback circuit. Design of a prototype and its operation with reference to typical specifications are discussed.

9.02 Air Vehicle Flight Testing

Session Organizer: Christian Rice, Naval Air Systems Command
Session Organizer: Robin Locksley, Naval Air Warfare Center

9.0201 AH-1Z Stores Compatibility Testing Lessons Learned

Christopher Barrett (Naval Air Warfare Center Aircraft Division)

The AH-1Z Cobra was a major upgrade of the AH-1W performed under the United States Marine Corps (USMC) H-1 Upgrades Program. Upgrades significant to weapons employment included a new rotor system, new stub-wing weapons stations, countermeasure dispensing system, and upgraded drive-train. During the test program, stores compatibility results were encountered which were not expected during test planning, including rocket gas ingestion and unsatisfactory 20-mm ammunition link separation.

9.0202 Evaluating Landing Aids to Support Helicopter/Ship Testing and Operations

Dean Carico (NAVAIR); Bernie Ferrier (Anteon Corporation)

There are no visual landing aids (VLA) on USA surface combatant ships to aid the pilot in anticipating a ship flight deck quiescent period. An analytic evaluation of the LPD concept was conducted at the NAVAIR Manned Flight Simulator (MFS) as a build-up prior to at-sea testing which is currently being scheduled. The NAVAIR MFS LPD data were compared to similar data from a RNAS Culdrose UK simulation conducted using similar analytic ship motion conditions. This paper reviews the manned flight simulation evaluations of the analytic landing period designator.

9.0203 Innovative Aircraft/Ship Visual Landing Aid (VLA) Test Tool

Robert Richards(Stottler Henke Associates, Inc.)

Stottler Henke has developed VERTICAL (VLA Experimental Resource for Testing Innovative Configurations And Lightings) for the US Navy. This test and design tool is being

used to support vertical takeoff and landing/rotorcraft ship Visual Landing Aids (VLA) test and design at the test team members' work area. This effort has been accomplished by utilizing MS Flight Simulator, FSUIPC, C++, and OpenFlight. This paper describes the productized version, whose prototype was originally described in an IEEE Aerospace 2005 paper.

9.0204 Aeroelastic Load Control Program: In-Flight Demonstration of Active Flow Control Technology

Raniel C. Hidalgo, Gregory J. Burgess, Reynaldo Enriquez, John L. Minor (USAF Test Pilot School, Edwards AFB), James Rogers (Air to Surface Test Flight, Munitions Division, Eglin AFB), Leonard Shaw (Air Force Research Laboratory)

The USAF Test Pilot School (TPS) and the Air Force Research Laboratory (AFRL) have partnered with Lockheed Martin and General Electric (GE) Global Research to execute the first flight test using Dual Bimorph Synthetic Jet (DBSJ) actuators to demonstrate the effectiveness of active flow control technology. The first phase of the Aeroelastic Load Control (ALC) program demonstrated the use of small, electronically controlled DBSJ actuators to mitigate the effects of turbulent airflow. The USAF TPS flew three flight tests that were dedicated to evaluating this technology, and validated our test configuration as an effective active flow control evaluation platform.

9.0205 Raptor Supersonic JDAM: Faster, Further, Longer

Major E. John Teichert III (USAF), Mr Eric Schutte (USAF), Mr John Waddington (Lockheed)

The F-22A Raptor's characteristics make it an ideal platform capable of destroying heavily defended ground targets in high threat regions . Once the subsonic air-to-ground Joint Direct Attack Munition (JDAM) capability became available, the warfighter immediately recognized the need for an expanded release envelope into supersonic regions to improve the pilot's tactical options. The testing for supersonic JDAM was accelerated to significantly increase the Raptor's air-to-ground combat lethality prior to Initial Operational Capability (IOC) in December 2005. This paper will detail the unique test effort, challenges, and lessons learned from the Raptor supersonic JDAM integration testing.

9.03 UAV Autonomy

Session Organizer: Robert Miller, Northrop Grumman Integrated Systems Western Region

9.0301 Autonomy Software: V&V Challenges and Characteristics

Johann Schumann, Willem Visser (NASA Ames)

The successful operation of unmanned air vehicles requires software with a high degree of autonomy. Such software is highly mission and safety critical. Due to its large size, complex architecture, and use of specialized algorithms (planners, constraint-solvers, etc.), autonomy software poses specific challenges for its verification, validation, and certification. We have carried out a survey among researchers and scientists at NASA to study these issues. A major focus of this survey was to evaluate verification and validation (V&V) issues, challenges, and advanced V&V tools that can help to mitigate software risks.

9.0302 Establishment of a System Operating Characteristic for Autonomous Wide Area Search Munitions

Brian Kish (USAF Test Pilot School); David Jacques, Meir Pachter (Air Force Institute of Technology)

The optimal employment of autonomous wide area search munitions is addressed. Target encounters are modelled using either a uniform or Poisson distribution. False target encounters are modelled using a Poisson distribution. Analytic system effectiveness measures are derived using applied probability theory. The effectiveness measures derived handle time-varying parameters. This allows the formulation and solution of optimization problems that maximize the probability of a target attack while at the same time constraining the probability of a false target attack. An increase in system effectiveness is demonstrated when parameters are dynamically controlled during a mission.

9.0303 Parallel Region Coverage Using Multiple UAVs

Amit Agarwal, Lim Meng Hiot, Nguyen Trung Nghia and Er Meng Joo (Nanyang Technological University, Singapore)

We consider the problem of minimizing the time needed to cover a contiguous rectilinear polygonal workspace, P of complexity N using k UAVs. We partition P into interior-disjoint polygons and make a one-to-one assignment of the polygons to the UAVs. The partition comprises polygons that are (a) rectilinear, (b) contiguous, (c) whose area-ratios equal the ratio of rates at which UAVs can do coverage and, (d) whose boundaries include points at which the respective UAV begins coverage. We prove that our algorithm runs in O(NlogN) time.

9.0304 Coordinated Control of Multiple UAVs for Time-Critical Applications

Isaac I. Kaminer, Oleg A. Yakimenko (Naval Postgraduate School); Antonio M. Pascoal (Instituto Superior Técnico)

The paper proposes a solution to the problem of coordinated control of multiple unmanned air vehicles (UAVs) to ensure collision-free maneuvers under strict spatial and temporal constraints. The solution proposed relies on the decoupling of space and time in the problem formulation. First, a set of feasible trajectories are generated for all UAVs using a new direct method of optimal control that takes into account rules for collision avoidance. A by-product of this step yields for each vehicle a spatial path to be followed, together with a desired nominal speed profile along that path. Each vehicle is then asked to...

9.0305 Hierarchical Decomposition Approach for Pursuit-Evasion Differential Game with Multiple Players

Jianhua Ge, Liang Tang (Impact Technologies, LLC); Johan Reimann, George Vachtsevanos (Georgia Institute of Technology)

Pursuit-evasion games are among the most widespread, challenging, and important optimization problems. This paper presents a hierarchical decomposition algorithm for pursuit-evasion differential games with multiple pursuers and multiple evaders. The developed algorithm is not only to reduce the complexity of the problem, but also to enable the problem to be solved in a distributed fashion. Consequently, when the scheme is to be implemented, it is possible to increase the speed of the algorithm by breaking it down into multiple independent computational processes.

Track 10: Software and Computing

Track Organizer: Robert Popp, Aptima, Inc.
Track Organizer: Sanda Mandutianu, Jet Propulsion Laboratory, Caltech

10.01 Advanced Software Verification Tools

Session Organizer: John Penix, NASA Ames Research Center

10.0101 Coverall Algorithm for Test Case Reduction

Preeyavis Pringsulaka, Jirapun Daengdej (Assumption University)

This paper proposes a technique called Coverall algorithm, the approach utilizes the advantage of Regression Testing where fewer test cases would lessen time consumption of the testing as a whole. The technique uses simple algebraic conditions to assign fixed values to variables (maximum, minimum and constant variables). The variables values would be limited within a definite range. After a comparative assessment of the technique, it has been confirmed that the technique could reduce number of test cases by more than 99%. The success is indeed significant; it represents a practical means for performing test cases generation automatically.

10.0102 Verification of Autonomous Systems for Space Applications

Guillaume Brat, Ewen Denney, Dimitra Giannakopoulou, Ari Jonsson (USRA/RIACS); Jeremy Frank (NASA),

Autonomous software can play an important role in future space applications. In general, the exploration capabilities of model-based systems give them great flexibility. Unfortunately, it also makes them unpredictable to our human eyes, both in terms of their execution and their verification. The traditional verification techniques are inadequate for these systems since they are mostly based on testing. In our work, we explore how advanced V&V techniques, such as static analysis, model checking, and compositional verification, can be used to gain trust in model-based systems. We also describe how synthesis can be used in the context of system reconfiguration.

10.0103 Flexible Generation of Kalman Filter Code

Julian Richardson (RIACS/USRA); Edward Wilson (Intellization)

In specific domains, code generators can quickly generate good code. Often, however, the code which is needed for an application lies slightly outside the domain of the generator. Two approaches for solving this problem - modifying the generator, and modifying the generated code - are both unsatisfactory. We describe a novel solution for this problem which extends the range of the generator enormously. We generate libraries of components instead of single programs, and provide a language permitting the user to combine those synthesized components in novel ways. We describe the use of this system to generate a complex state estimator.

10.02 Agent-Based Systems for Aerospace

Session Organizer: Sanda Mandutianu, Jet Propulsion Laboratory, Caltech

10.0201 Multi-agent System for Managing Human Activities in Space Operations

Debra Schreckenghost, R. Peter Bonasso (Metrica, Inc)

In manned space operations today, the astronauts' activity schedules are preplanned and adjusted daily on Earth. We have developed the Distributed Collaboration and Interaction (DCI) multi-agent system to investigate automating aspects of human activity management. The DCI System assists (1) plan generation, (2) human activity tracking, (3) plan revision, and (4) mixed initiative interaction with the plan. We have deployed and evaluated the DCI system at JSC to assist control engineers in managing anomaly handling activities for automated life support systems. Based on this evaluation, we conclude that agent assistance for schedule management can reduce anomaly response time.

10.0202 COGENCY: Collaborative Communities of Grid-aware Intelligent Agents

Jidé Odubiyi (Bowie State University); Chris Rouff (SAIC); Paul Chi (Bowie State University)

Collaborative communities of grid-aware intelligent agents (COGENCY) is an environment under development for disseminating information from sensor webs. COGENCY is an environment with semi-autonomous, proactive, and collaborative software entities that can represent human actions, and adapt to changing environments. The two major technologies (grid computing and grid-aware intelligent agents) being applied to COGENCY promote approaches for developing a domain-specific solution that exploits the needed infrastructure reliable file transfer, storage management, security, etc. that grid computing provides. COGENCY is currently being developed to support the Future Combat System (FCS), but can extend into engineering disciplines and business operations.

10.0203 AEGONE-Agent-Enabled, Grid-Oriented, and Just-in-time Network of Experts

Walt F Truszkowski (NASA Goddard Space Flight Center); Jidé B Odubiyi (Bowie State University & SEGMA LLC)

Consider a model developed by a multi-disciplinary team of scientists. This model will be used by researchers to support some scientific investigation. However, this investigation might be hampered if the researcher needs to interface (on the fly) with the members of the inter-disciplinary team responsible for the development of the model. This paper presents an innovative integrated solution--Agent-Enabled, Grid-Oriented Network of Expert agents (AEGONE), to the problem of gaining on-demand access to multi-disciplinary team members responsible for model development and access to multiple distributed models in a user-friendly transparent way.

10.0204 An Agent-Based Approach to Distributed UAV and Sensor Planning Systems

Raymond Budd, Dana Moore (BBN)

Significant work has been done in enhancing concurrency and overall efficiency of planning systems for unmanned sensors deployments. Concurrency is important for a variety of reasons including creating scalable and ‘pluggable’ systems. In this paper, we document work done with the Task Expansion Engine (TEE) and software agents based on the COUGAAR architecture and results achieved using this foundation and discuss current and potential applications possible with this framework...

10.0205 An Agent-based Tetrahedral Walker

Charles Sebens (MIT); Walt Truszkowski (NASA Goddard Space Flight Center)

ANTS (Autonomous Nano Technology Swarm) SMART (Super Miniaturized Addressable Reconfigurable Technology) architectures were initiated at the Goddard Space Flight Center (GSFC) to develop new kinds of robotic structures capable of: goal-oriented motion, changing its form to optimize its function, adapting to new environmental demands, and/or repairing itself. To begin to explore the possibilities of these concepts and the possible application of multi-agent control, a series of increasingly complex roving shapes leading up to the tetrahedron were considered. The goal is to have the structure move from an initial location to a specified goal location.

10.0206 Agent-Based Simulation to Evaluate Technology and Concepts for the National Airspace System

Shailendra Mehta (Purdue University); and Simulex, Inc.); Liviu Nedelescu (Lockheed Martin), Michael Nolan (Purdue University); and Simulex, Inc.); Kyle Krull (Simulex, Inc.); Jim Whitford (Simulex, Inc.); Mike Pfleiderer (Lockheed Martin); Cheemun Foong (Simulex, Inc.)

The paper describes an agent-based simulation developed to test the benefits of inserting airline dispatch technology as well as a collaborative rerouting concept for the National Airspace System (NAS). The approach taken was to create agents that could model the major stakeholders of the NAS, such as the Federal Aviation Administration (FAA) and the major airlines. Attributes and objectives were defined with the help of exerts for each of the different agents, while rules of engagement defined their respective interaction. The benefits of the technologies and concepts considered were verified through a number of metrics, including operating costs.

10.03 Computational Modeling

Session Organizer: Darrell Terry, Northrop Grumman, ES

10.0301 On Detection Networks and Iterated Influence Diagrams: Application to a Parallel Distributed Structure

Haiying Tu, Satnam Singh, Krishna R. Pattipati, Peter Willett (University of Connecticut)

The similarities between detection networks and influence diagrams, as well as their advantages and disadvantages are discussed using a parallel network structure as an example paradigm. A framework, termed iterated influence diagrams, which combines influence diagrams and person-by-person optimization, is proposed to take advantage of the benefits from both representations. The key purpose is the relaxation of one of the major constraints of a regular influence diagram, viz. decision nodes must be ordered. As a consequence, influence diagram can also be used to represent and solve distributed detection problems, i.e. find the optimal decision policies for all the decision makers.

10.0302 Low-Thrust Mission Trade Studies with Parallel, Evolutionary Computing

Seungwon Lee, Ryan Russell, Wolfgang Fink, Richard Terrile, Anastassios Petropoulos, Paul von Allmen (Jet Propulsion Laboratory)

This paper presents parallel, evolutionary computing methods to rapidly determine feasiblity and thoroughly explore trade spaces for low-thrust missions. The developed methods utilize distributed computing to speed up computation, and use evolutionary algorithms to explore trade spaces. The methods are coupled with the Primer Vector theory to solve an optimal thrust control problem. The required computational time is orders of magnitude shorter than that of other optimizers due to the distributed computing, the significant reduction of search space dimension with the Primer Vector theory, and the efficient and synergistic exploration of the remaining search space with evolutionary computing.

10.0303 A Framework for the Design Optimisation of Aerospace Platforms using Intelligent Technologies

Lorenz Drack (Defence Science and Technology Organisation, Australia).)

A framework for the global shape optimisation of aerospace platforms is discussed, using Soft Computing methodologies to enable the solving of complex multiple-objective and multi-disciplinary problems in the design of these platforms. Its application to a complex design problem in aerospace engineering is detailed, being the design of quiet and efficient propellers. The interpretation of optimiser behaviour is achieved through the stochastic analysis of the design states produced by the optimiser during its search, allowing the designer to establish the effect of objectives and constraints in the cost function.

10.04 Enterprise Mission Management

Session Organizer: Michael Keeley, Lockheed Martin

10.0401 Command and Control Concepts within the Network-Centric Operations Construct

Paul W. Phister Jr, John D. Cherry (Air Force Research Laboratory);

Military operations are being transformed to address the new threats facing the global economy; such as, Global War on Terrorism. At the heart of this transformation is a new theory of warfare, called Network Centric Warfare. It's sub-divided into: Network Centric Infrastructure and Network Centric Operations. Applications such as Predictive Battlespace Awareness, Cyber Operations, and a concept called the Situational Awareness Infosphere is presented and how they apply to NCW. An example of how the situational awareness infosphere can be applied to space and how it is affected by NCW along with a corresponding list of technology challenges is discussed.

10.05 Human-Computer Interaction

Session Organizer: Howard Neely, HRL Laboratories, LLC

10.0501 A Review of Time Critical Decision Making Models and Human Cognitive Processes

Ron Azuma, Mike Daily (HRL Laboratories); Chris Furmanski

From a general cognitive perspective, decision making is the process of selecting a choice or course of action from a set of alternatives. A large number of time critical decision making models have been developed over the course of several decades. This paper reviews both the underlying cognitive processes and numerous decision making models primarily from a military context.

10.0502 Automatic Speech Recognition Fusion Approach to Unsupervised Speaker Clustering and Labeling

Aaron Lawson (Research Associates for Defense Conversion); Mark Huggins (Lockheed-Martin); John Grieco (Air Force Research Laboratory); Shane Galligan (Research Associates for Defense Conversion); David Harris (Oasis Systems)

This paper describes a fully unsupervised approach to speaker clustering and labeling employing speech recognition (ASR) technology to bootstrap speaker identification (SID). An algorithm that combined these two technologies was able to correctly cluster and label 299 NATO ship-to-ship transmissions with an accuracy of 89% in an on-line (no a priori training) scenario. This fusion approach out-performed ASR alone by 23.6%, and out-performed manually-trained VQ-SID by 12.7% and GMM/UMB-SID by 8.6%. This paper demonstrates that, under certain circumstances, unsupervised, self-organizing systems can be more effective than manually-trained ones.

10.0503 Sensing Super-position: Visual Instrument Sensor Replacement

David. A. Maluf, John F. Schipper (NASA Ames)

The coming decade of fast, cheap and miniaturized electronics and sensory devices opens new pathways for the development of sophisticated equipment to overcome limitations of the human senses. This project addresses the technical feasibility of augmenting human vision through Sensing Super-position using a Visual Instrument Sensory Organ Replacement (VISOR). The current implementation of the VISOR device translates visual and other passive or active sensory instruments into sounds, which become relevant when the visual resolution is insufficient for very difficult and particular sensing tasks.

10.06 Information Management and Collaborative Engineering

Session Organizer: Carl Puckett, Jet Propulsion Laboratory, Caltech

10.0601 Knowledge Mining Application in ISHM Testbed

William J. McDermott, David A. Maluf, PhD. Rick Alena (NASA Ames);, Mohana Gurram (Universities Space Research Association), Peter Robinson (NASA Ames Research Center), Kevin Bass((QSS Group, Inc.);.), Daniel P. Duncavage (NASA Johnson Space Center)

The scope of Integrated System Health Management (ISHM) is the end-to-end autonomous management of subsystems, systems and systems of systems. Among ISHM's components is management of data, information, and knowledge to detect and diagnose anomalies, and propose mitigation procedures for crew implementation. Complex systems such as the International Space Station (ISS) generate a large amount of data, over 160,000 documents that are distributed across disparate systems. But this data is fragmented and applications are unable to interoperate. In addition, the lack of a seamless mechanism for ensuring use of latest, best information hinders development of much needed modeling, simulation and...

10.07 Information Technologies for Counter Terrorism

Session Organizer: Robert Popp, Aptima, Inc.

10.0701 Operationally Significant Patterns of Association

William C. Hardy and Richard W. La Valley (SAIC)

An association between two persons is a reported fact that can reasonably be assumed to indicate they probably communicate with each other. Much of the information on suspected terrorists comprises collections of such associations without information to support determination of evidence of cooperative involvement in pursuit of a common goal or objective. A major challenge for information technology is to develop tools for discovering such stronger relationships in collections of associations gathered from disparate sources. This paper describes patterns of association that are indicators of such organizational activity that can be derived with elementary pattern recognition techniques.

10.0702 Metrics-Based Test and Evaluation of Group Detection Software for Counter-Terrorism

Thomas Garwin, Matthew P. Crozat, Brian L. Merrell (SAIC, Advanced Systems and Concepts)

This paper describes experience with an integrated set of test methods developed to evaluate the technical accuracy and real-world value of group detection algorithms as applied to link datasets of varying size and characteristics. The testing includes an automated software harness to score the algorithms against representative datasets that are generated by a controlled random process from known ground truth. It also applies novel statistical benchmarks and techniques to evaluate the value of the algorithms as applied by analysts to real intelligence data where ground-truth is absent.

10.0703 Applying LSI and Data Reduction to XML for Counter Terrorism

S. Demurjian, S. Rajasekaran, R. Ammar, I. Greenshields, T. Doan, and L. He (University of Connecticut)

This paper presents a survey of latent semantic indexing (LSI) techniques and strategies, including select LSI software packages. Next, this paper reviews data reduction techniques which either reduce the number of data points or the dimensionality of the data, and examines random projections as a preprocessing step for reduction. Then, this paper explores the application of LSI to XML data. Lastly, the paper proposes an approach of LSI and data reduction for XML documents that transitions from support vector machines to random projections to LSI, and considers the usage of semantics of web-based documents that are captured via XML tags.

10.0704 An Infrastructure for Automating Information Sharing in Analytic Collaboration

Gregory A. Mack (SAIC); David Fado (SAIC); M. Brian Blake (Georgetown University); Dominic Widdows (MAYA Design)

This paper reports on developments toward a next generation collaboratory supporting small groups of analysts (or policy makers) engaged in joint analysis and problem solving. The work reported in this paper “automates what ought to be automated,” differentiating between what machines do well and what humans do well. It describes an infrastructure that automates much of the information exchange between analysts while at the same time creating an environment that facilitates insight sharing among analysts in a community of interest.

10.08 Novel Information Technologies for Asymmetric Threats

Session Organizer: David Cousins, BBN Technologies

10.0801 Creative Activity Modeling for Handling Surprises in Asymmetric Attacks

Tapanan Yeophantong, Jirapun Daengdej, Pratit Santiprabhob (Assumption University)

Asymmetric warfare today has become a mean for less militarily advanced troops to battle against the more militarily advanced ones. One common characteristics of these attacks is the element of surprise. Asymmetric attackers try to ensure that no one knows what or where the attack is to take place to ensure maximum damage. In this work, we propose a framework for which a system may anticipate asymmetric threats creatively by building up a

list of threatening events that may occur, based on various forms of knowledge obtainable by the system to perform the creative process of generation and evaluation.

10.0802 Hardware Accelerated Algorithms for Semantic Processing of Data Streams

Stephen G. Eick (SSS Research), John W. Lockwood, Ron Loui, Andrew Levine (Washington University), Justin Mauger (SAIC), Doyle Weishar (SAIC), Alan Ratner (NSA), John Byrnes (HNC)

There is a need within the intelligence communities to analyze massive streams of multilingual unstructured data. Mathematical transformation algorithms are effective at interpreting multilingual, unstructured data; but high computational requirements of such algorithms have prevented their widespread use. We have developed a system that performs computation using Field Programmable Gate Array (FPGA) hardware at high data rates. The system processes data carried over TCP/IP network flows. We have performed a series of experiments processing multilingual documents and we compare techniques to generate basewords for our semantic concepts, score documents, and discover concepts across a variety of processing operational scenarios.

10.0803 An Architecture for Streaming Coclustering in High Speed Hardware

John Byrnes, Richard Rohwer (HNC Software / Fair Isaac Co.)

We seek to learn the semantics of a data stream at optical line speed. We focus on text data, but the techniques developed should apply to broad modalities of network data wherever appropriate features can be computed rapidly enough. We consider a custom hardware system designed to categorize documents based on feature clusters and document clusters that have been learned offline on standard general-purpose computers, and we present a technique for extending this system to permit online learning from arbitrarily large data sets.

10.0804 A Survey of Techniques to Visualize Streaming Textual Datasets

Stephen G. Eick (SSS Research, Inc.); David Bruce Cousins (BBN)

In this paper we examine the applicability of several well know document visualization programs to the newly arising problem of visualizing the processing of streams of textual datasets. We identify several view points into a modern textual stream processing flow where the operation and efficiency of the system can be improved by the appropriate visualization technique. We examine some of the physical scalability limits of visualizing large quantities of information. We then put forth several criteria and evaluate some well known text visualization systems for use in this new environment.

10.0805 Framework for Enhanced Perception of NLOS Threats and Targets

Dana Moore, Dzulkifli Scherber, William Wright (BBN)

As seen in the current Operation Iraqi Freedom, the operational environment in which today's warfighter operates is extremely complex and challenging. In the urban terrain, for example, warfighter survivability, lethality and operational effectiveness are directly related to the quality of situational awareness (SA), which is based on Essential Elements of Information (EEIs) that currently flow down through radio communications with the commander and analysts. EEIs represent information regarding the enemy and environment critical to a given operational mission and are based on intelligence gathered from either battlefield sensing assets or other HUMINT. As battle and mission objectives change, initial information...

10.09 Quantitative and Computational Social Sciences to Understand 21st Century Strategic Threats

Session Organizer: Robert Popp, Aptima, Inc.

10.0901 Assessing Nation-State Instability and Failure

Robert L. Popp (Aptima, Inc); Stephen Kaisler (SET Associates); David Allen (SRS Technologies); Claudio Cioffi-Revilla (Goerge Mason University); Kathleen Carley (Carnegie-Mellon University); Mohammed Azam (University of Connecticut);t); Anne Russell (SAIC); Nazli Choucri (MIT); Jacek Kugler (Claremont Graduate Schools)

DARPA initiated a six-month Pre-Conflict Anticipation and Shaping (PCAS) initiative to demonstrate the utility of quantitative and computational social science models (Q/CSS) applied to assessing the instability and failure of nation-states. We also explored a mechanism for sensitivity analysis of Q/CSS model results to selected parameters, and we also implemented a mechanism to automatically categorize, parse, extract and auto-populate a bank of Q/CSS models from large-scale open source text streams. This paper describes the motivation and rationale for the program, the Q/CSS models and mechanisms, and presents results from some of the models.

10.0902 Automated Population of Dynamic Bayes Nets for Pre-Conflict Analysis and Forecasting

Anne Russell, Mark Clark, Gregory Mack (SAIC); Sudipto Ghoshal, Krishna Pattipati (Qualtech Systems)

Conflict-ridden nation-states - regional instability, WMD proliferation, drugs and terrorism among others – grow in importance to the United States and other global powers. Pre-Conflict Analysis is a labor-intensive effort for skilled social scientists laboring through data for social indicators that precipitate hostility and conflict. As a result, the time that sentient beings require to analyze events and build reports precludes rapid warnings. This paper demonstrates that automated transform-based categorizers and linguistic pattern extraction tools, combined with Hidden Markov and Bayesian network modeling techniques can automate the most arduous aspects of conflict analysis and forecasting in the social sciences.

10.0907 Supporting Decisions with (Less Than Perfect) Social Science Models

Steve Bankes, Steven Popper, Robert Lempert (Evolving Logic)

For many decision support applications, our knowledge is best expressed as computer models, and so it is important to develop valid means for aggressively exploiting anticipatory models. Unexamined direct application of engineering practices to these situations can lead to either model misuse, or the failure to exploit all the available knowledge in supporting important decisions. Robust inference provides an alternative basis for model exploitation. In particular, by using search to aid in the discovery of decisions that perform satisfactorily across all plausible scenarios, we can utilize less than perfect models to support important decisions.

10.0908 Understanding & Modeling State Stability: Exploiting System Dynamics

Nazli Choucri, Christi Electris, Daniel Goldsmith (Brandeis), Dinsha Mistree, Stuart E. Madnick (MIT), J. Bradley Morrison (Brandeis), Michael D. Siegel (MIT), Margaret Sweitzer-Hamilton (Brown)

The potential loss of state stability in various parts of the world is a source of threat to U.S. national security. Every case is unique, but there are common processes. Accordingly, we develop a system dynamics model of state stability by representing the nature and dynamics of 'loads' generated by insurgency activities, on the one hand, and by articulating the core features of state resilience and its 'capacity' to withstand these 'loads', on the other. The problem is to determine and 'predict' when threats to stability override the resilience of the state and, more important, to anticipate propensities for 'tipping...

10.10 Software Development Methodologies

Session Organizer: Joseph Urban, Arizona State University

10.1001 Ontological Approach to Improving Design Quality

Allyson Hoss, Doris L. Carver (Lousiana State University)

This paper describes a common ontology that integrates software specification knowledge and software design knowledge in order to facilitate the interoperability of formal requirements modeling tools and software design tools with the end goal of detecting errors in software designs. The approach focuses initially on the integration of Unified Modeling Language (UML) with the formal requirements modeling language, Knowledge Acquisition in autOmated Specification (KAOS), in order to help automate the detection of inconsistencies in UML designs, thereby enhancing the quality of the original design and ultimately integrating the multiple views inherent in UML.

10.1002 An Executable Choreography Framework for Dynamic Service-Oriented Architectures

Faisal Akkwai (Northwestern University), Daryl P. Fletcher (SAIC), Thomas Cottenier (Illinois Institute of Technology), Daniel P. Duncavage (NASA Johnson Space Center), Richard L. Alena (NASA Ames); Research Center), Tzilla Elrad (Illinois Institute of Technology)

The Executable Choreography Framework (ECF) is a middleware-level framework that targets dynamic and decentralized service compositions. The ECF combines transparent context propagation with aspect-oriented software composition techniques to dynamically refine the default control and data flow of service invocations. The framework provides a ground for experimentation with dynamic and distributed workflows, and a base to assess their safety and applicability when deployed across organizational boundaries.

10.1003 Software Architecture of Sensor Data Distribution in Planetary Exploration

Charles Lee, John Ossenfort, Richard Alena, Thom Stone, Ed Walker, Hugo Notario (NASA Ames)

Data from mobile and stationary sensors, will be vital in planetary surface exploration. The distribution and collection of sensor data in an ad-hoc wireless network presents unique challenges. Some of the conditions encountered in the field include: irregular terrain, mobile nodes, routing loops from clients associating with the wrong access point or repeater, network routing reconfigurations caused by moving repeaters, etc. To mitigate the effects of these impairments, robust and reliable software architecture tolerant of communications outages must be implemented. This paper describes such a robust and reliable software infrastructure that meets the challenges...

10.1004 On Certain Theoretical Developments Underlying the Hilbert-Huang Transform

Semion Kizhner, Karin Blank, Thomas Flatley, Norden E. Huang, David Petrick, Phyllis Hestnes (NASA Goddard Space Flight Center)

One of the main traditional tools used in scientific and engineering data spectral analysis is the Fourier Integral Transform and its high performance digital equivalent – the Fast Fourier Transform (FFT). Both carry strong a-priori assumptions about the source data, such as being linear and stationary, and of satisfying the Dirichlet conditions. A recent development at the National Aeronautics and Space Administration (NASA) Goddard Space Flight Center (GSFC), known as the Hilbert-Huang Transform (HHT), proposes a novel approach to the solution for the nonlinear class of spectral analysis problems.

10.1005 The Deep Impact Flight Software Architecture

Richard T. Hess Jr, Jacob Torrez (Ball Aerospace and Tehnologies Corp.)

Ball Aerospace & Technologies Corp. has developed an Advanced SPacecraft ElectroNics (ASPEN) Flight Software, architecture using industry best practices that promote high quality, adaptable flight software. Design best practices such as architectural abstraction layers, modular software, task-based applications, and message-based communication have all contributed to this flexible and reusable flight system. Developmental best practices such as daily builds and automated regression tests have also played a part in the success of the ASPEN Flight Software. This paper provides details on how these best

practices were incorporated into the ASPEN Flight Software and used on Deep Impact and subsequent missions...

10.1006 Agile Language Development: The Next Generation

William Wright, Dana Moore (BBN Technologies)

Whether true or not, most of us would agree that such languages as Java have changed forever the way we develop and deploy applications. In this paper, we propose that in order to evolve the next generation of distributed, rapidly developed applications, lightweight languages (what were once called “scripting languages”) such as Python, Ruby, PHP, ECMAScript, Groovy, and JudoScript are critical to provide infrastructure for component-based applications, to support rapid prototyping, and more and more to create next generation applications themselves.

10.11 Use of XML in Space Systems

Session Organizer: Michael Van Steenberg, NASA`s Goddard Space Flight Center

Session Organizer: Shirley Tseng, Infinite Global Infrastructures

10.1101 CompreX: Further Developments in XML Compression

Kirk J. Swanson, Jason Judt (Architecture Technology Corporation)

The use of Extensible Markup Language (XML) has become increasingly widespread. While XML is an extremely powerful and flexible tool, as more Internet applications are being used in bandwidth or computationally limited environments the limitations of XML become apparent. In these environments, the significant file size inflation caused by conversion to XML becomes a prohibitive factor. Architecture Technology Corporation is currently developing a modular approach to XML specifically for application in a bandwidth limited environment. Initial work has focused on three aspects of XML compression, collectively known as CompreX.

10.1102 AstroLogic: Using XML in a Spacecraft-Focused Client-Server System

Scott A. McDermott (AeroAstro Inc.)

AstroLogic is an XML-based messaging system which uses the client-server model of information networking. Each subsystem acts as a client (requesting resources from other subsystems) and as a server (providing its functionality as a resource to other subsystems). This model applies within the spacecraft, across a spacecraft constellation, and with ground utilities, as one network. This paper will explore some of the more unexpected benefits of XML in this application, particularly: escaping from "bit-width limited" expressions of numerical data; capturing time-based information in a sensible and universal structure; and the ability to integrate tools and third-party standards without added effort.

10.12 Web++: Semantics, Ontologies, and Agents

Session Organizer: Sanda Mandutianu, Jet Propulsion Laboratory, Caltech

10.1201 An Approach for Detecting Deception in Agents

Pimphun Pradchayakool, Jirapun Daengdej (Assumption University); Supannika Koolmanojwong (University of Southern California)

The role of intelligent agents has been recognized as important in electronic communication. Since the intelligent agent is developed to be cleverer, more complex, and yet uncontrollable, a number of problems have recently been recognized. Examples of theses problems are: how to identify whom we can trust, how we know which agent is lying and how to manage information that is acquired from them. We propose two related techniques to deal with some of theses issues. The first relates to the trust measurement of agents and the second involves detecting a deception approach that is able to adjust weights by...

10.1202 Realizing Organizational Collaboration through Semantic Mediation

Sri Gopalan, Sandeep Maripuri, Brad Medairy (Booz Allen Hamilton)

Realizing organizational collaboration requires a greater level of information sharing between knowledge agents – both the people within an organization and the information systems that support them. Achieving this level of information transparency relies on fundamental improvements in today's systems and data mediation architectures. This paper describes how Semantic Web technologies can be leveraged within the context of Service Oriented Architectures to support dynamic, meaningful exchange of information both within and across organization boundaries.

10.1203 Geospatial Semantic Web: Architecture of Ontologies

Dave Kolas, Mike Dean, John Hebeler (BBN Technologies)

An effective ontology architecture using the semantic web enables the development of a semantic geospatial system that forges multiple geospatial data sources and services into a powerful cross-discipline knowledge tool . This paper outlines five interrelated ontologies that support a complete semantic geospatial system. The ontologies contribute to a working example that illustrates the advantages of semantic technologies in addressing geospatial challenges. The outlined advantages include complex query decomposition, seamless integration of non-semantic services, and dynamic customization to a specific domain of interest. We encourage the development of these ontologies into useful standards for further exploiting geospatial data and services.

10.1205 Perspective Models as a Means for Achieving True Representational Accuracy

Kym J. Pohl (CDM Technologies Inc.)

Accurate and expressive representation of subject matter is fundamental to the effectiveness and longevity of a context-oriented, decision-support solution. However, to achieve true representational accuracy and utility, it is critical to both acknowledge and exploit distinctions in user perspective. Perspective models provide a realistic means for managing such expressive environments. Further, to be truly effective, the concept of perspective models is partnered with a supportive model development process that effectively parcels the development of individual perspective models with the model users that inherently possess substantial domain and use-case expertise.

10.13 PANEL: XML Deployment

Session Organizer: Ryan Detter, NASA-GSFC

Track 11: Diagnostics, Prognostics, and Health Management

Track Organizer: Andrew Hess, Joint Strike Fighter Program Office
Track Organizer: David Kleinman, Naval Postgraduate School

11.01 PHM Roadmaps, Strategies and Implementation

Session Organizer: Chris Pomfret, Treble One LLC

11.0101 An Integrated Approach to the Development of an Intelligent Prognostic Health Management System

Rob Callan, Brian Larder and John Sandiford (Smiths Aerospace)

The construction of successful Prognostic Health Management (PHM) systems requires the bringing together of a range of technologies, possibly from many suppliers. Careful management of technology integration is required. Proposed standards have been written to allow different technologies to communicate. But there is also a need to define formal frameworks so that technologies are integrated in a coherent manner. This paper presents some practical applications of PHM technologies that fulfill functions within different layers of the PHM process. These applications are then used to explain how these different functional technologies integrate through a common probabilistic framework.

11.0102 Integrating development- and support tools for PHM in Saab 39 Gripen.

Torbjorn Fransson (Saab AB)

This paper describes how the workflows to define pilot warnings, recording needs and fault isolation are integrated in order to reduce development time and reuse data. There are over 500 failure modes and about 100 maintenance fault reports defined for the Gripen Aircraft. The impact of a failure is dependent on equipment configuration and thus the required pilot actions or corrective maintenance actions will differ between the variants. In complex failure situations it is also important to find the primary fault. Ability to perform quick upgrades of aircraft in service at low cost is also essential.

11.0103 Benefits of IVHM- An Analytical Approach

Zachary C. Williams (The Boeing Company)

Support requirements and health management are significant operational drivers on large military weapons systems and large commercial aircraft. The integration of health management into the up-front design of these systems should include a detailed benefit analysis that includes all of the benefactors of operational performance that a truly integrated health management system can bring. These benefactors are the Original Equipment Manufacturers (OEMs), the mission operators, command/control elements, fleet management, and maintenance operations. Each of these functional areas has unique processes that can be identified and measured. The performance improvement on a system can be evaluated before design dollars are ever...

11.0106 Wire integrity Management Using Sensors On-board Manned Aero-spacecraft

James Cockrell(NASA); Philip Wysocki(ASRC); Ralph Hodgson, Sidney Bailin (TopQuadrant Inc)

In this paper we assume that in-situ wire sensors will be incorporated into ISHM systems. We focus on the business case for the inclusion of Wire Integrity Management in future vehicle design. We explore ground processing scenarios, rather than in-flight. Our expectations are that the greatest value of in-situ wire integrity management will be in savings of cost, scheduling, invasiveness, and risks. Ground processing includes: vehicle recovery, fault diagnosis, access, closeout and safing, tooling, repairs, spares provisioning, testing and validation, and preflight/postflight preparations.

11.02 Fixed Wing and/or Rotary Wing Program Applications

Session Organizer: Andrew Hess, Joint Strike Fighter Program Office
Session Organizer: Keith Sellers, Boeing

11.0201 Recorders, Reasoners and Artificial Intelligence Integrated Diagnostics on the C-17 Aircraft

Bala Chidambaram (The Boeing Company)

Boeing has developed an Integrated Diagnostic System to optimize maintenance on military transport aircraft. The Integrated Diagnostic System comprises an On-board Recorder and a Ground-Based Reasoner that analyzes recorded data. The functions of the Ground-Based Reasoner (GBR) include root-cause identification, filtering of false alarms, and maintenance action prioritization. The technologies used include expert systems, data mining technologies and Bayesian analyses. The GBR provides a framework for incorporating these technologies into a software tool. The tool has an intuitive GUI designed to help the maintenance technician with everyday tasks. The Integrated Diagnostic System is currently undergoing testing on the C-17 aircraft.

11.0202 Discriminant Analysis for Helicopter Rotor Vibration Prognostics

Ruben Avila, Pat Banerjee, David He (University of Illinois); Eric Bechhoefer (Goodrich Fuels and Utility Systems)

Traditionally, preventive maintenance has the drawback of being too expensive because of unnecessary replacements. Corrective maintenance involving replacement or repair after a failure is also expensive because of down time. In this paper, we present discriminant analysis and stepwise discriminant analysis for vibration prognostics. The goal is prediction of failures in drive train components of helicopters, specifically tail rotor drive shaft or engine input shaft.. The method has been applied to make predictions of vibrations in the main rotor shaft of Sikorsky helicopter UH-60, using Goodrich Health and Usage Management System (HUMS). The purpose of these predictions is to...

11.0203 Fixing BIT on the V-22 Osprey

Kerry Westervelt (NAVAIR)

The V-22 Osprey measured an unsatisfactory high BIT false alarm rate of 92% during its first Operational Test And Evaluation Phase in 2000. On a good note, the V-22 did exceed its operational objectives for BIT fault detection and fault isolation rates. Afterwards, the Blue Ribbon Panel report identified the need to fix false alarms. Correction of false alarms then became a high priority issue on the program. Therefore, a success-oriented engineering approach was developed and implemented to mature the diagnostics system in order to meet the operational requirements.

11.03 PHM for Turbine and Propulsion Engines

Session Organizer: Thomas Brotherton, The Intelligent Automation Corp.

11.0301 Recent Case Studies in Bearing Fault Detection and Prognosis

Carl Byington, Rolf Orsagh, Kallappa Pattada, Jeremy Sheldon, Mike DeChristopher, Sanket Amin, Jason Hines (Impact Technologies)

This paper updates current efforts by the authors to develop fully-automated, online incipient fault detection and prognosis algorithms for drivetrain and engine bearings. The authors have developed and evolved ImpactEnergyTM, a feature extraction and analysis driven system that integrates high frequency vibration/acoustic emission data, collected using accelerometers and other sensors such as a laser interferometer to assess the health of bearings and gearboxes in turbine engines. The techniques presented in this paper are tested and validated in a laboratory environment by monitoring multiple bearings on test rigs that replicate the operational loads of a turbomachinery environment.

11.0302 Propulsion Safety and Affordable Readiness Engine Health Management Plan

Brian K. Beachkofski (Air Force Research Laboratory)

A new initiative was started to address Department of Defense safety and affordable readiness for legacy turbine engines. By using the GOTChA/ApPRoVal methods, a baseline research plan was established that is based on prognostics and health management. This paper outlines the decision process, investment strategy, projected return on investment, validation, and transition strategies.

11.0303 The SECAD Project - Vulnerability Reduction via Propulsion Control Logic

Alan D. Pisano (General Electric Aviation); Charles E. Frankenberger III (Naval Air Warfare Center, Weapons Division)

Digital propulsion controls provide the foundation for adding capabilities to enable the next level of increased survivability for both war-time and peace-time damage scenarios. The SECAD project has made significant progress toward the development of a complete system to not only diagnose, but also to react to non-catastrophic damage to the engine gas path in real-time and thus preserve thrust needed to enable mission completion, intelligent mission re-planning, or just getting the pilot “out of harms way”. Test results of a highly successful “full-envelope” demonstration using an F414-GE-400 turbofan engine at the NAWCWD Survivability Laboratory are presented.

11.0304 Validation of a COTS EHM Solution for the JSF Program

Somnath Deb, Venkata N. Malepati (Qualtech Systems), Michel D. Paquet, Baban Baliga (Pratt & Whitney)

This paper presents results from a recent study conducted under the JSF program to evaluate and validate the COTS reasoner, TEAMS-RT, selected by Pratt and Whitney for onboard diagnosis of faults in the JSF F135 engine. We compare the TEAMS-RT reasoner’s computational performance and diagnostic accuracy against a proven P&W legacy reasoner. The models were auto-generated from high quality information on LRC/module failure modes and rates from the FMECA, and HRCs issued by the FADEC. The results show a slight improvement in diagnostic accuracy and substantial improvement in computational performance by the TEAMS-RT reasoner.

11.0306 Modeling and Simulation of Vibration Signatures in Propulsion Subsystems

Nancy Lybeck, Brogan Morton, Sean Marble (Sentient Corporation); Andrew Hess (Joint Strike Fighter Program Office); John Kelly (NAWCAD)

A fundamental problem in the development and validation of PHM technologies is the general shortage of realistic fault signature data. While healthy signatures can be obtained from operational systems, faults are relatively rare and difficult to observe. The PHM community must rely primarily on bench level seeded fault test data collected under a limited set of conditions. To augment physical data, a modeling and simulation toolset is being developed for the vibration signatures of faulted components in propulsion subsystems such as gearboxes. Several examples are presented comparing simulated vibration signals to actual test data.

11.04 Diagnostics and PHM for System Components and Subsystems

Session Organizer: Michael Roemer, Impact Technologies, LLC

11.0401 Investigation of Tapered Roller Bearing Damage Detection Using Oil Debris Analysis

Paula J. Dempsey (NASA Glenn Research Center); Gary Kreider, Thomas Fichter (The Timken Company)

A diagnostic tool was developed for detecting fatigue damage to tapered roller bearings. Tapered roller bearings are used in helicopter transmissions and have potential for use in high bypass advanced gas turbine aircraft engines. This tool was developed and evaluated experimentally by collecting oil debris data from failure progression tests on one healthy and three predamaged bearings performed by The Timken Company in their Tapered Roller Bearing Health Monitoring Test Rig. Results indicate oil debris mass is a good

predictor of damage on tapered roller bearings and a fuzzy logic model enables an easily interpreted diagnostic metric.

11.0402 Improving the Maintenance Process and Enabling Prognostics for Control Actuators using CAHM Software

Matthew Watson, Carl S. Byington (Impact Technologies, LLC)

The authors are developing an approach for improved maintenance of hydraulic servovalves and mechanical actuators, which have traditionally been plagued with high incidences of Can Not Duplicate (CND) errors, high sparing requirements, high maintenance costs, and low operational readiness. The approach, which is initially targeted toward implementation in an intermediate test data environment, employs both data-driven and model-based algorithms to provide diagnostics and prognostics (remaining useful life prediction). Advanced reasoners are also being developed to interpret BIT results for better fault isolation. These diagnostic algorithms will not only help isolate faults, but will also provide a gray-scale health assessment of...

11.0403 Simulation-Based Health and Contingency Management

Michael J. Roemer, Liang Tang, Greg Kacprzynski, Jianhua Ge (Impact Technologies); George Vachtsevanos (Georgia Tech)

This paper presents a concept and associated software test bench for simulation-based health and contingency management that can be applied to integrated vehicle health management architectures. The simulation-based design test bench was developed in the Matlab/Simulink™ environment and can be applied to various platforms for developing, testing and verifying automated prognostic and health management technologies and fault accommodation strategies. Specifically, this paper introduces the required software components and integrated health management and adaptive control architecture for performing these tasks. The Simulink™ modules provide for “plug ‘n play” integration of vehicle models, prognostic and health management (PHM) algorithms, and adaptive control.

11.05 Diagnostics and PHM for Avionics & Electrical Power Systems

Session Organizer: Carl Byington, Impact Technologies, LLC

11.0501 Why Prognostics for Avionics?

Herbert Hecht (SoHaR Incorporated)

The ability to plan and control maintenance activities is becoming increasingly important because of the shortage of skilled personnel and the complexity of current avionics products. The benefits of prognostics are well established for mechanical and electromechanical equipment, and this motivates the extension of the technique to the electronics field. But there are very large differences between mechanical and electronic components in failure mechanisms, in the design process, and in the physical dimensions of the parts subject to failure that preclude direct migration of the prognostic techniques. These differences are examined in detail and a procedure for developing prognostics specifically...

11.0502 Prognostic Health Management for Avionic Systems

Rolf Orsagh, Doug Brown, Pat Kalgren, Carl Byington (Impact Technologies); Andrew Hess, Thomas Dabney ((Joint Strike Fighter Program Office);)

Maintenance of aircraft electronic systems has traditionally been performed in reaction to reported failures or through periodic system replacements. Recent changes in weapons platform acquisition and support requirements have spurred interest in application of prognostic health management (PHM) concepts developed for mechanical systems to electronic systems. The approach, development, and validation of prognostics for two types of electronic equipment are discussed in this paper. The two applications, a switch-mode power supply and a GPS receiver were selected based on their relatively high failure rates

and relevance to many commonly used avionics systems. The method identifies prognostic features by performing device...

11.0503 Aircraft Electrical Power Systems Prognostics and Health Management

Kirby Keller (The Boeing Company)

The Aircraft Electrical Power Systems Prognostics and Health Management (AEPHM) program, presently being worked by Air Force Research Laboratories (AFRL), Boeing, and Smiths Aerospace, has developed and demonstrated health management (diagnostics, prognostics and decision aids) algorithms and system integration approaches for electrical power systems. The first phase of the program, which ended in July of 2005, addressed electric actuation, fuel pumps/valves and arc fault protection. The second phase is addressing power generation. Algorithm development is based on seeded fault and accelerated wear testing in hardware laboratory facilities.

11.0504 An Intelligent Hierarchical Approach to Actuator Fault Diagnosis and Accommodation

Xiaodong Zhang, Yong Liu, Chiman Kwan, Roger Xu (Intelligent Automation Inc.); Rolf Rysdyk (University of Washington)

This paper presents a novel intelligent hierarchical approach to automatically detecting, isolating, and accommodating faults in flight control systems. The proposed architecture has three main components. First, a nonlinear fault diagnosis scheme is used to detect and isolate the fault. Second, a controller module consists of a primary nominal controller and a secondary adaptive fault-tolerant controller. While the nominal controller can be any existing conventional flight control system, the secondary nonlinear adaptive controller is designed to maintain acceptable control performance after fault detection. Third, a reconfiguration supervisor makes decision regarding controller reconfiguration and control reallocation by using on-line diagnostic information.

11.0505 A Hybrid Prognostic Model Formulation System Identification and Health Estimation of Auxiliary Power Units

Pradeep Shetty (Honeywell Technology Solutions Lab); Dinkar Mylaraswamy (Honeywell Laboratories); Thirumaran Ekambaram (Honeywell Technology Solutions Lab)

Prognostic health monitoring (PHM) is an important element of condition-based maintenance and logistics support. The accuracy of prediction and the associated confidence in prediction, greatly influences overall performance and subsequent actions either for maintenance or logistics support. Accuracy of prognosis is directly dependent on how closely one can capture the system and component interactions. Traditionally, such models assume constant and univariate prognostic formulation---that is, components degrade at a constant rate and are independent of each other. Our objective in this paper is to model the degrading system as a collection of prognostic states (health vectors) that evolve continuously over time.

11.0506 Real Time Estimation of Battery Impedance

John Morrison (Montana Tech); William Morrison (Qualtech Systems, Inc.)

Electrochemical Impedance Measurement Systems use the Bode analysis technique to characterize the impedance of an electrochemical process. It is a well established and proven technique. The method is effective but time consuming, as the process is serial. There is interest in real time acquisition of battery impedance for control and diagnostics over a limited frequency range. To support this need a true parallel approach is proposed that uses a single acquired time record of the battery response with duration compatible to a real time control process. The time record duration is the battery impedance sample period. If that sample period...

11.0507 Development and Test of a Real Time Battery Impedance Estimation System

R. G. Hoffmann, J. E. Slade, J. L. Morrison, (Montana Tech of The University of Montana)

Electrochemical Impedance Measurement Systems use the Bode analysis technique to characterize the impedance of an electrochemical process in a well established and proven technique. The method is effective but time consuming, as the process is serial. There is

interest in real-time acquisition of battery impedance for control and diagnostics over a limited frequency range. To support this need, a true parallel approach has been developed by Montana Tech of The University of Montana (Montana Tech) that uses a single acquired time record of the battery response with duration compatible to a real-time control process. The system excites a test battery...

11.0508 Field Data Evaluation and Continuous Health Assessment of Critical Avionics Subsystem Degradation

Philip L. Dussault (AMRDEC); Carl S. Byington, Patrick W. Kalgren, Anthony J. Boodhansingh (Impact Technologies, LLC)

Effective utilization of existing avionics on-board and at-wing data, can realize improved maintenance, survivability, and critical failure rates via degrading component identification prior to critical failure. The authors demonstrated feasibility of onboard and at-wing prognostics using field data in an Army case study of a mission-critical targeting subsystem. The two use cases, complimentary embedded and at-wing paradigms, illustrate multiple source data mining, anomalous indicator trending and ranking, system-level modeling of on-board BIT, automated ambiguity reduction through advanced reasoning, and avionics system prognostics. These techniques incorporate engineering test results as ground truth feedback and validation of the Prognostic Health Management process.

11.06 Diagnostics and PHM Applied to Aircraft Structures

Session Organizer: Giulio Calvello, Joint strike fighter program office

11.0601 Optimisation of Fusion and Decision Making Techniques for Affordable SPHM

Hesham Azzam, Frank Beaven, Malcolm Wallace (Smiths); Iain Hebden (BAES)

This paper describes the evolution of a certifiable practical SPHM system by Smiths and BAES and details recent advances and optimisation of the algorithms. This includes data correction algorithms, mathematical networks and dynamic models. The algorithms have been developed to support both legacy and modern aircraft. Therefore, the algorithms have been optimised after blind validation on legacy data covering 15 years of military operations. The optimisation has been based on model-based knowledge, sensitivity analysis and genetic algorithms. The genetic optimisation has been targeted at data mining techniques and neural networks with unique activation functions combining sigmoid, linear and inverse functions.

11.0602 Embedded Resistive Strain Sensors for Harsh Environments

Christopher Gouldstone, Jeff Brogan, Rob Greenlaw, Richard J Gambino, Jonathan Gutleber (MesoScribe Technologies, Inc.); Sanjay Sampath, Jon Longtin (Stony Brook University)

Strain gages developed using high-definition direct write technology enable direct bonding to substrates without an adhesive layer. Effects of hysteresis, creep, and temperature limitations common to adhesively-bonded gages are mitigated. Manufacture and installation of the gage (and lead wires) are automatic and simultaneous, reducing preparation time and cost. Using this method, industrial-grade strain gages have been fabricated and tested. Standard gage resistances between 120-350ohms have been achieved on grids smaller than 10mm-sq. Thermal plasma-sprayed laser-cut resistive gages have achieved gage factors of 1.3, operating linearly and repeatably for more than 10,000 cycles between ±1000 microstrain.

11.0603 Disk Crack Detection and Diagnosis for Gas Turbine Engines

Wenyi Wang (Defence Science and Technology Organisation)

Health monitoring for gas turbine engines will be an essential component for any prognostics and health management (PHM) system of the next generation military aircraft. This paper presents a technique of detecting and diagnosing disk cracks of gas turbine engines. Analysis results have shown that the trending of an unbalance index (UI) acquired from shaft proximity data can be effective in detecting changes of crack-induced unbalance. Results have also shown that Nyquist plots of the complex UI can be used to extract

valuable diagnostic information on the relationship between initial mass unbalance and crack-induced unbalance.

11.07 Algorithms and Advanced Concepts for Diagnostics and PHM

Session Organizer: David Kleinman, Naval Postgraduate School

11.0701 Adaptive Control of Actuator Lifetime

Levent U. Gokdere, Alexander Bogdanov, Stephen L. Chiu (Rockwell Scientific); Kirby J. Keller, John Vian (The Boeing Company)

The harder an actuator is pushed to its performance limits, the shorter its lifetime becomes. Existing actuator controllers are typically designed to optimize performance and robustness, without considering the actuator`s operational lifetime. However, it is often desirable to trade off performance for extended lifetime in order to reduce vehicle maintenance cost and improve vehicle safety and mission readiness. We present two adaptive control algorithms for managing the lifetime of motors in electromechanical actuators. The first algorithm provides tracking control of a desired motor lifetime. The second algorithm provides adaptive trade-off between motor performance and lifetime based on mission needs.

11.0702 Layered Classification for Improved Diagnostic Isolation in Drivetrain Components

Matthew J. Smith, Carl S. Byington, Patrick Kalgren, Ashish Parulekar, Michael DeChristopher (Impact Technologies, LLC)

This paper investigates the enhancement of current vibration data based health monitoring techniques for helicopter drivetrain components. The authors adapted feature processing algorithms and developed a hierarchical classification system to discriminate between multiple bearing failure mechanisms and provide improved maintenance decision aiding. The data was collected from CH-47D/E (Chinook) swashplate bearings on a seeded fault test stand. The authors outline the method of using vibration-monitoring data to detect incipient bearing and drive train faults. Fault classification was established by applying hierarchal principle component analysis (PCA) from baseline and faulted bearing data at a full range of flight operating conditions.

11.0703 Analytical Mechanical Diagnostic Benefits: Case Studies

David Hochmann, Greg Baringer, (Goodrich FUS)

The current success of mechanical diagnostics systems generates increased expectations for future performance. Many of the successful diagnostics condition indicators employed in current mechanical diagnostic systems have evolved from empirical techniques or iterative methodologies. Goodrich Fuel and Utility Systems (FUS) which is a manufacturer of advance diagnostic systems has been quantifying many of the successful diagnostic indicators and processing techniques. This paper will provide an overview of the benefits that the analytical knowledge has provided for mechanical diagnostics through the presentation of several case studies. Case studies include results from a gear diagnostics, bearing diagnostics, and indexer diagnostic examples.

11.0704 Mechanical Diagnostics System Engineering in IMD-HUMS

Eric R. Bechhoefer, Eric Mayhew (Goodrich Fuel and Utility Systems)

This paper addresses the system engineering required to integrate the vibration processing, decision algorithms, thresholding and filtering to give the operator the best representation of component health. A model based method of thresholding is presented based on statistical properties of a function (e.g. health) of distributions (condition indicator). The integration of the system allows IMD-HUMS to have a high degree of certainty in the information given to the operator. The system engineering insures that the recommendation for component maintenance has a low probability of false alarm while maintaining a high probability of component fault detection.

11.0705 On Handling Dependent Evidence and Multiple Faults in Knowledge Fusion for Engine Health Management

Valerie Guralnik, Dinkar Mylaraswamy, Harold Voges (Honeywell)

In this paper, we introduce the notion of mutually exclusive diagnostic subsets. In our approach, elements of the frame of discernment are subsets of faults that cannot be mistaken for each other, rather than failure modes. The theory of Dempster-Shafer is extended to handle dependent evidence for simple and separable belief functions. We present examples from a Honeywell auxiliary power unit to illustrate our modified D-S method of evidence aggregation.

11.0706 On False Alarm Mitigation

Joel R. Bock, Tom Brotherton, Paul Grabill (Intelligent Automation Corporation); Doug Gass (NAVAIR – (Joint Strike Fighter Program Office);); Jonathon A. Keller (U.S. Army AMCOM, Aviation Engineering Directorate)

Condition-based Maintenance (CBM) of military vehicles or industrial machines presumes the capability to correctly detect faults in components or subsystems. Two types of errors can occur during automated fault detection: (1) missed detections or (2) false alarms. The consequence of either type of error is that a failed component may not be replaced when necessary, or alternatively, may be unnecessarily serviced due to a false alarm. This paper presents selected aspects of the aircraft health-monitoring problem, new algorithmic approaches to user-controllable false alarm rates, and includes pragmatic details of false alarm mitigation on currently-deployed military aircraft systems.

11.0711 Use of Non-Gaussian Distribution for Analysis of Shaft Components

Eric Bechhoefer (Goodrich Fuel and Utility Systems), Andreas Bernhard (Sikorsky Aircraft)

For the rotating machinery, a standard set of CI are shaft order one, two and three. We present evidence that the distribution of the magnitude vibration is Rayleigh for nominal (health components) and the Rice for components that are damaged. A model for shaft magnitude is used which describes the Rayleigh distribution. The Rice distribution is the general case of the Rayleigh distribution when the component has nonzero centrality. Threshold setting procedures for the Rayleigh distribution are given for anomaly detection and for failure detection and compared to Gaussian model. Examples are given against real world conditions.

11.08 Application of Baysean Networks for Diagnostics and PHM

Session Organizer: LiJie Yu, General Electric Global Research Center

11.0801 An Efficient Framework for the Conversion of Fault Trees to Diagnostic Bayesian Network Models

K. Wojtek Przytula (HRL Laboratories LLC); Richard Milford (Boeing)

In this paper we present an efficient and largely automated method for developing diagnostic Bayesian Network models. The models are created by exploiting existing domain knowledge in the form of reliability fault trees and diagnostic observation lists. The algorithms for conversion of the trees and databases into Bayesian Network models have been embedded in a C++ software tool and tested on examples of fault trees ranging from 10 to 800 nodes, which were developed for satellite systems.

11.0802 Using Sensitivity Analysis to Validate Bayesian Networks for Airplane Subsystem Diagnosis

Haiqin Wang (The Boeing Company)

In this paper, we introduce our practice of building Bayesian networks for airplane subsystem diagnosis. We use an efficient sensitivity analysis method to validate our diagnostic models. The algorithm is based on relevance-based decomposition in joint tree computation framework. We also describe how to use sensitivity analysis in model elicitation procedure to validate Bayesian network models based on our practice of model building for airplane subsystem fault isolation.

11.0803 Not-So-Naive Bayesian Networks and Unique Identification in Developing Advanced Diagnostics

John Sheppard, Stephyn Butcher (The Johns Hopkins University); Mark Kaufman, Craig MacDougall (NSWC Corona)

We study the problem of performing diagnosis on systems using models based on data collected about specific units. We discuss an alternative class of Bayesian model that we call the "not-so-naive" Bayesian network (NBN). We rely on the Department of Defense (DoD) Unique Identification (UID) program and discuss the NBN in the context of the UID program as a means of tracking and deriving probabilities for creating the network. Finally, we focus on the specific problems encountered and lessons learned from working with a large, real-world database for the US Navy`s STANDARD Missile.

11.09 Maintenance, Ground Support and Enterprise Systems

Session Organizer: Somnath Deb, Qualtech Systems, Inc.

11.0901 An Intelligent Agent-based Self-evolving Maintenance and Operations Reasoning System

Liang Tang, Gregory J. Kacprzynski (Impact Technologies, LLC); Joel R. Bock (Intelligent Automation Corporation); Michael Begin (NAVAIR - JSF Program Office)

PHM represents a key component of the JSF Autonomic Logistics system. To meet the challenge of developing advanced technology to integrate PHM information from a variety of different sources into a dynamically evolving knowledge-base for JSF, a prototype software system named the Self Evolving Maintenance and Operations Reasoner (SEMOR) is proposed. SEMOR utilizes intelligent software agents in JADE, both Model-based and Case-based Reasoners and reinforcement learning modules to continually evolve PHM knowledge base using maintenance and operations feedback. This paper presents the software system design, describes key technical components, demonstrates example application scenarios and concludes with remarks on future developments.

11.0902 Recent Advances in IEEE Standards for Diagnosis and Diagnostic Maturation

John W. Sheppard (The (The Johns Hopkins University);); Timothy J. Wilmering (The Boeing Company)

Efforts by the Department of Defense to increase use of commercial or dual-use technologies have resulted in the levying of new requirements on the exchange of diagnostic and maintenance information. These requirements have led to the creation or revision of several IEEE standards. In this paper, we efforts in the development of IEEE STD 1232 (AI-ESTATE), IEEE P1636 (SIMICA) and its relationship to AI-ESTATE, and a new XML-based exchange format being incorporated into AI-ESTATE, SIMICA, and related standards to satisfy exchange requirements under the DoD and industry-led Automatic Test Markup Language (ATML) initiative.

11.0903 Framework for Post-Prognostic Decision Support

Kai Goebel, Naresh Iyer, Piero Bonissone (GE Global Research)

We describe a decision support system (DSS) for use in operational decision making with PHM-specific data. Challenges arise from conflicting information from PHM modules, seemingly contradictory and changing requirements from operations as well as maintenance for a multitude of different systems within strict time constraints. The DSS will enable users to make optimal decisions based on his expression of trade-offs between different prognostic and external information sources. This is accomplished through guided evaluation of different optimal decision alternatives under operational boundary conditions using user-specific and interactive collaboration. An illustrative example result is presented.

11.0904 Discovering Atypical Flights in Sequences of Discrete Flight Parameters

Suratna Budalakoti(University of California, Santa Cruz); Ashok N. Srivastava (NASA Ames); Ram Akella (University of California, Santa Cruz)

This paper describes an effort conducted towards discovering anomalies in flight data discrete parameter sequences. The inputs to our system are records from flights for a given class of aircraft and destination. The system delivers a list of potentially anomalous flights, with reasons why the flight was tagged as anomalous. The goal is to help safety experts

discover significant human factors issues such as pilot mode confusion. The work is an extension of Integrated System Health Management (ISHM), with the goal of evaluating the combined health of a class of aircraft at a given destination.

11.0905 A Model Based Approach to Constructing Performance Degradation Monitoring Systems

Gautam Biswas (Vanderbilt University); George Bloor (The Boeing Company)

Tightly choreographed enterprises require ongoing knowledge of their member systems capabilities and performance levels to adapt and maintain effective operations. Performance degradation curves for member system functionalities must be continually monitored and made available to operators, mission operations, and maintenance personnel. This paper discusses a model-based approach to designing and building an embedded vehicle performance monitoring (VPM) system that leverages physics models of the vehicle components that are endemic to the simulation based design acquisition process. The simulation-based approach coupled with degradation and performance monitoring sets up the ability to predict future vehicle behaviors and performance under degraded conditions.

11.0906 Enterprise Search Tasks in IVHM Practice

David R. Throop (The Boeing Company)

IVHM tasks both manage large flows of data and access large stores of textual information. These tasks are special cases of the general integrated problem of data mining and enterprise search. We review current approaches with particular attention to problems characteristic of IVHM searches. Emerging COTS software uses taxonomies and ontologies to find documents which otherwise be missed, to narrow searches that return too many results, and to navigate through large search results. Ontologies are formal models of knowledge for particular domains. We discuss sources of aerospace taxa and ontologies, security considerations, and some open issues in ontology representation.

11.0907 Performance analysis using a Fuzzy rule base representation of the Cooper-Harper rating

Chris Tseng (San Jose State University); Pramod Gupta (QSS Inc.); Johann Schumann (RIACS (NASA Ames)

The Cooper-Harper rating of Aircraft Handling Qualities has been adopted as a standard for measuring the performance of aircraft since it was introduced in 1966. Aircraft performance, the ability to control the aircraft, and the degree of necessary pilot compensation are three major key factors for deciding the aircraft handling qualities in the Cooper-Harper rating scheme. We formulate the Cooper-Harper rating scheme as a fuzzy rule-based system and use it to analyze the performance of the aircraft controller. The automatic estimation of the current system-level handling quality provides valuable up-to-date information for diagnostics and vehicle health management.

11.10 Sensors, Signals and Data Fusion

Session Organizer: Jonathan Cook, Materials and Structures Group, UK MOD

11.1001 PHM Sensor Implementation in the Real World a Status Report

Ari Novis (Pratt & Whitney); Honor Powrie (Smiths Aerospace)

The growing field of Diagnostics involves moving technology from cutting-edge to commonplace. The issues of aircraft cost, weight, and safety severely constrain the implementation while demanding increased value. PHM sensors monitoring systemic rather than localized conditions often show the most value by covering a greater number of components for a given weight. Such sensors also often cross physical, organizational, and occasionally corporate boundaries. This paper examines some of the considerations with implementing propulsion PHM in the real-world environment of the JSF aircraft program. The Electrostatic monitoring system will serve as a case study to highlight these issues.

11.1002 Gas Path Debris Monitoring for F-35 Joint Strike Fighter Propulsion System PHM

Honor Powrie (Smiths Aerospace); Ari Novis (Pratt & Whitney)

The F-35 Joint Strike Fighter (JSF) Prognostics and Health Management (PHM) program is redefining the baseline for aircraft PHM. The objective is a management system that will enable the F-35 aircraft to identify and report its own maintenance requirements, maximising aircraft use and minimising logistical overhead. The propulsion system PHM sensor suite incorporates several emerging technologies, including gas path debris monitoring. This paper provides a top-level description of the technology, its implementation and integration for F-35 and the development route planned to achieve the maturity level required for initial service release.

11.1003 FUMS Fusion and Decision Support for Intelligent Management of Aircraft Data

Hesham Azzam (Smiths), Jonathan Cook (UK MOD), Peter Knight (Smiths), Ed Moses (UK MOD)

The Fleet and Usage Management System (FUMS) has been developed by Smiths and the UK MOD to enable aircraft life management and diagnostic and prognostic improvements. This system is now in daily operation supporting Chinook aircraft operational in the UK and deployed world-wide. This paper describes FUMS tools including engine applications for vibration analysis, life/fleet management and performance degradation monitoring. The paper illustrates intelligent fusion of off-line wear debris data and on-line HUMS data and the automated management of HUMS condition indicators. The FUMS applications have significantly reduced the workload of MOD personnel and provided greater diagnostic and prognostic capability.

11.1004 Fusing Competing Prediction Algorithms for Prognostics

Kai Goebel (GE Global Research)

Two fundamentally different approaches can be employed to estimate remaining life in faulted components. One is to model from first principles the physics of fault initiation and propagation. Alternatively, an empirical model of condition-based fault propagation rate can be developed using data from experiments in which the conditions are controlled or otherwise known and the component damage level is carefully measured. Fusing the results of the two approaches produces a result that is more robust than either approach alone. In this paper, we describe how to fuse these prognostic predictors. Results are presented from rig test data.

11.1005 Embedded Temperature and Heat Flux Sensors for Advanced Health Monitoring of Turbine Engine Components

Jonathan Gutleber, Jeffrey Brogan, Richard J Gambino, Christopher Gouldstone, Robert Greenlaw (MesoScribe Technologies, Inc.); Sanjay Sampath, Jon Longtin (Stony Brook University); Dongming Zhu (NASA)

MesoScribe Technologies has developed a Direct Write process for producing embedded, conformal, thick film sensors. Thermocouple and heat flux sensors can be fabricated directly onto engineering components and embedded into functional coatings. In this work, embedded thermocouples and heat flux sensors were deposited and subjected to a number of high temperature tests. Initial testing yields Seebeck coefficients within 3% of commercial thermocouples as well as demonstrates that embedded Type K thermocouples can survive various static and cyclic high temperature testing protocols approaching 1150°C.

11.11 Wireless and Networked Sensors for PHM Applications

Session Organizer: Susan George, RLW, Inc.

11.1101 Development of a Vibration-Powered Wireless Temperature Sensor and Accelerometer for Health Monitoring

Sue George (RLW, Inc.)

This paper describes and evaluates the continued development of a prototype vibration-powered, wireless sensor for use in Condition Based Maintenance (CBM) applications. A

major impediment to more widespread implementation of wireless, self-powered sensors has been a lack of sensors that can scavenge enough energy to operate. The sensor described in this paper solves that problem by implementing low-power electronics and improved energy scavenging technology. Developed by RLW, Inc. of State College, PA, the S5NAP™ sensor runs off power scavenged from the ambient vibrations of the platform to which it is attached. It acquires and wirelessly communicates temperature and acceleration measurements.

11.1102 Analyzing and Optimizing the System of Sensors

Amir Fijany, Farrokh Vatan (Jet Propulsion Laboratory)

In this paper, we propose a new algorithmic approach for design of a sensor system that maximizes the diagnosability of the system and minimizes the cost of the sensor placement. This approach also allows us to analyze extend of the coverage of the sensor system and to determining its diagnosability degree.

11.1103 A Kennedy Space Center Implementation of IEEE 1451 Networked Smart Sensors and Lessons Learned

Rebecca Oostdyk, Carlos Mata (ASRC Aerospace); Jose Perotti (NASA Kennedy Space Center)

To meet the need for more specific and reliable information from ground support instrumentation systems and future spacecraft sensors and to support Intelligent Health Management Systems (IHMS), Kennedy Space Center has consulted the IEEE 1451 family of smart-sensor standards to develop smart network elements (SNEs). SNEs provide reliable signal conditioning to raw sensors, complex data processing, and communication capabilities with a light implementation of the IEEE 1451 family of standards. They are capable of assessing the health of the raw sensors and the electronics and the reliability and tolerance of the measure-ment, and they relay this information to higher-level systems.

11.12 Materials-Based Prognostics and Prognostic Modeling

Session Organizer: Andrew Hess, Joint Strike Fighter Program Office
Session Organizer: Lorenz Nasser, VEXTEC Corporation

11.1201 Predicting the Remaining Life of Propulsion System Bearings

Sean Marble, Brogan Morton (Sentient Corporation)

This paper describes a comprehensive experimental study of bearing spall progression and a physics-based model being developed under a NAVAIR SBIR and the DARPA Prognosis Program. The model computes the spall progression and time to failure based on operating conditions, and uses diagnostic feedback to reduce prediction uncertainty. Model predictions compare very well to experimental fault progression data, which has demonstrated that propagation is better behaved than once thought. For turbine engine thrust bearings with a typical mission mix, the prognostic window (first detection to failure) is on the order of 100 flight hours, which provides ample reaction time.

11.1202 Probabilistic Model Based Algorithms for Prognostics

David He, Shenliang Wu, Pat Banerjee (University of Illinois at Chicago); Eric Bechhoefer (Goodrich)

In this paper, two prognostic algorithms to accurately predict the state of a complex system as a function of time are presented. The algorithms are developed based on a hidden semi-Markov model (HSMM) and validated on a real-world helicopter rotor track and balance prognosis problem. It is shown that the developed prognostic algorithms provide a good performance in predicting the time to the next required rotor track and balance action for two different application scenarios.

11.1203 Prognostics Usefulness Criteria

J. Kevin Line, N. Scott Clements (Lockheed Martin Aeronautics)

WE have developed the usefulness criteria to guide the design and verificaton of prognostic algorithms on the F-35. The usefulness criteria are a list of goals related to aircraft supportability which can be used to define the minimum acceptable time to maintenance

indication for the prognostic algorithm. The goals in the usefulness criteria were applied to each prognostic algorithm in the F-35 PHM system.

11.1204 Challenges, Issues, and Lessons Learned Chasing the Big P: Real Predictive Prognostics Part 2

Andrew Hess, Maj. Giulio Calvello, Peter Frith (Joint Strike Fighter Program Office); Stephen J. Engel, David Hoitsma (Northrop Grumman Corp.)

The desire and need for real predictive prognostic capabilities have been around for as long as man has operated complex and expensive machinery. Recently, stringent Diagnostic, Prognostic, and Health Management (PHM) capability requirements are being placed on new applications, in order to enable and reap the benefits of new and revolutionary Logistic Support concepts. This second paper in a series continues to explore background, benefit impacts, and architectures; highlight some additional design challenges and issues; discuss prognostic capabilities for electronic systems; review strategies for prognostic capability verification and validation; and draw heavily on other related lessons learned from previous and...

11.1205 Electronics Reliability Prognosis Through Material Modeling and Simulation

Loren Nasser, Maggie Curtin (VEXTEC Corporation)

Electronic systems are multilayered devices consisting of different materials with inherent variability. Thermal cycling occurs during system operation which results in thermo-mechanical fatigue induced material failure. This project uses state-of-the-art material modeling to predict degradation of circuit board elements as a means for “simulated fault detection.” This effort has been focused on the specific aspect of solder fracture and fatigue since electronic industry statistics have attributed this failure issue as a driving factor in system reliability. This project demonstrates feasibility for using conventional sensing, combined with thermal modeling, to predict solder degradation and equipment failure.

11.1206 Prognostics Modeling of Solder Joints in Electronic Components

Jeffrey W. Simons, Donald A. Shockey (SRI International)

We describe a methodology for performing materials-based prognostics for failure in electronic components. The component considered here is a gull-wing lead power supply chip on a DC/DC voltage converter PWB assembly. As a first step, three-dimensional finite element analyses are performed to determine macrostrains in the solder joints due to thermal or mechanical cycling of the component. In the second step, the macrostrains are used to set boundary conditions for a probabilistic micromodel that can simulate initiation and growth of cracks in the microstructure of the solder. Here, we describe the first step of the methodology.

11.1207 A Board-Level Prognostic Monitor for MOSFET TDDB

Douglas Goodman, J. Ralston-Good, R. Graves (Ridgetop Group,Inc.); B. Vermeire (Arizona State University)

A prognostic cell to monitor time-dependent dielectric breakdown and electronic aging of integrated circuits has been designed and fabricated.

11.13 Land Vehicle and Ship PHM Technologies Relevant to Aircraft Applications

Session Organizer: Jeffrey Banks, Penn State Applied Research Laboratory

11.1301 A Demonstration of Embedded Health Management Technology for the HEMTT LHS Vehicle

Jeffrey Banks (Penn State ARL)

This paper describes the development and implementation of a prototype embedded health management system for the U.S. Army HEMTT M1120A2+ vehicle. Diagnostic, advanced diagnostic and prognostic technologies were developed and implemented for four of the vehicles subsystems including the engine, transmission, load handling system and main vehicle batteries. This interface was developed to provide vehicle operational status data and sub-system health information in an actionable format that is simple to understand and intuitive to operators and maintainers.

11.1302 Applied Neural Network for Navy Marine Gas Turbine Stall Algorithm Development

Daniel Caguiat (Naval Surface Warfare Center)

Naval Surface Warfare Center conducted stall testing on a General Electric LM2500 gas turbine engine. This paper discusses the feasibility of employing a neural network approach to detect and output a compressor stall margin value and associated risk of compressor stall for Navy LM2500 gas turbines. Utilizing the data collected, with a MATLAB-based neural network approach, NSWC developed an algorithm to detect and trend stall margin that can eventually be used in an early stall warning system.

11.1303 Diagnostic End to End Monitoring & Fault Detection for Braking Systems

Brian J. Murphy, Jeff C. Banks, Mitchell S. Lebold, Karl Reichard (The Pennsylvania State University)

The performance of a braking system is fundamental to the operation of most vehicles. There are very few diagnostic systems that monitor the health of braking systems and even fewer that can automatically detect early stage failures with the reliability required for such a vehicle subsystem. The systems that can accomplish these tasks are restricted due to size, weight. This paper describes a technique developed at the Penn State Applied Research Laboratories Systems Operations and Automation Department for low physical impact fault detection and monitoring of hydraulic vehicular braking systems...

11.1304 Prognostics and Advanced Diagnostics for Improving Steady-State and Pulse Reliability

Yevgeny Macheret, Phillip Koehn (Institute for Defense Analyses)

Achieving high reliability of military platforms is critical for reducing operating costs and increasing operational availability and combat readiness. This paper describes results of a comparative analysis of two approaches to improving platform reliability.

11.1305 Modeling of Hydraulic Systems Tailored to Diagnostic Fault Detection Systems

Brian J. Murphy, Jeffrey C. Banks, Mitchell S. Lebold, Karl Reichard (The Pennsylvania State University)

The consistent and reliable operation of hydraulic systems is paramount for many systems. From spacecraft to the most basic automotive bottle jack an undetected failure can have significant consequences if not noticed in time. This paper describes a technique developed at the Penn State Applied Research Laboratories for the design of hydraulic simulation models that pre-incorporate fault diagnostic design. This technique is being applied to a military HEMTT supply vehicle that utilizes a palletized hydraulic loading system. The test vehicle has a hydraulic system that is fully instrumented with sensors for this work.

11.14 IVHM for Space Applications

Session Organizer: Serdar Uckun, NASA Ames Research Center

11.1401 Emerging Technologies for V&V of ISHM Software for Space Exploration

Martin S. Feather (Jet Propulsion Laboratory); Lawrence Z. Markosian (QSS Group, Inc.)

High reliability systems often rely on fault protection to recognize and respond to faults, preventing catastrophic failures. Integrated System Health Management (ISHM) extends fault protection to more complex systems, and to maintain capability not just averting catastrophe. Forms of ISHM have been used in system maintenance but less so in a “fault protection” role during actual operations. This is partly because of the challenges of verification, validation and certification of ISHM systems. We argue that state-of-the-practice V&V techniques will not suffice for complex ISHM systems, but that maturing software engineering assurance technologies show promise for addressing these V&V challenges.

11.1402 ISS as a Testbed for Advanced Health Management and Automation Technologies

Carlos Garcia-Galan (Honeywell); Dan Duncavage (NASA Johnson Space Center); Olu Olofinboba (Honeywell Laboratories)

The Space Exploration Program will require new technologies in a wide spectrum of applications, from vehicle subsystem components to health management and automation

applications. Highly relevant operational environments and data are necessary to successfully develop, mature, and validate new technologies destined for Systems and Mission Management capabilities. The ISS provides a unique, long-term on-orbit operations environment, which can be used to mature and validate technologies that will directly impact on-board vehicle/crew autonomy and mission operations. This paper evaluates using ISS as a testbed for developing advanced health management and automation technologies for future space systems.

11.1403 Entropy Based Anomaly Detection Applied to Space Shuttle Main Engines

Adrian Agogino, Kagan Tumer (NASA Ames Research Center)

Automated, model-free anomaly and fault detection using large collections of sensor data is vital to increasing safety and reducing maintenance costs of complex aerospace systems, such as the Space Shuttle Main Engine. This paper presents two general, model-free, analysis methods based on Shannon entropy that detect anomalies. The first is based on system entropy and detects trends, while the second is based on "cluster entropy" and detects subtler clues in the data. Using test-stand data, this approach revealed a fault in the high pressure fuel turbo-pump early in the test-run and subsequent cascaded faults later in the test run.

11.1404 Enabling the Discovery of Recurring Anomalies in Aerospace Problem Reports

Ashok N. Srivastava (NASA Ames); Ram Akella, Vesselin Diev, Sakthi P. Kumaresan, (UC Santa Cruz); Dawn M. McIntosh (NASA Ames); Emmanuel D. Pontikakis, Zuobing Xu, Yi Zhang (UC Santa Cruz)

This paper describes the results of a significant research and development effort conducted at NASA Ames Research Center to develop new text mining algorithms to discover anomalies in free-text reports regarding system health and safety of two aerospace systems. We discuss two problems of significant import in the aviation industry. The first problem is that of automatic anomaly discovery concerning an aerospace system through the analysis of tens of thousands of free-text problem reports that are written about the system. The second problem that we address is that of automatic discovery of recurring anomalies.

11.1405 Spacelift Telemetry Acquisition and Reporting Limit Checking System

K. Richardson, Z. Petrosyan, R. Abbott, D. Scott, M. Hajianpour, S. Ghantiwala, K. Marabyan, A. Quan, R. Crawford, D. Nystrom (The Aerospace Corporation)

During two recent launch countdown activities, The Aerospace Corporation (Aerospace) engineering analysts recognized the need for a tool to make it easier to identify and monitor unexpected telemetry measurement values to allow timely anomaly resolution. To satisfy this need Aerospace personnel developed an automated limit-checking system to monitor launch vehicle pre-flight measurements. A database that holds the measurement information and limits, a real-time measurement archive, and a limit-checking engine and data visualization client application comprise the Limit Checking System. The real-time limit-checking system was used by analysts at Aerospace to monitor a Titan IVB vehicle during B30 and B26 launches.

11.1406 Bearing Health Monitoring and Life Extension in Satellite Momentum/Reaction Wheels

Sean Marble, David Tow (Sentient Corporation)

Bearing faults in reaction wheels are a significant life- and performance-limiting factor in spacecraft. The failure mechanisms in these applications and the monitoring technologies needed are significantly different from most terrestrial and aircraft systems. This paper describes field experience and experimental data on bearing faults in satellite applications, and presents new monitoring technologies that allow optimal control of lubrication, thus extending life and preventing torque anomalies. The technologies described may also be useful in aircraft applications such as hanger bearings where loss of lubrication, rather than contact fatigue, is the primary failure mechanism.

Track 12: Mission Ops Concepts, Technologies, & Experiences

Track Organizer: Jody Gunn, Jet Propulsion Laboratory, Caltech

12.01 Emerging Technologies and Operations Strategies

Session Organizer: John Bristow, NASA
Session Organizer: Trevor Sorensen, University of Kansas

12.0101 James Webb Space Telescope XML Database: From the Beginning to Today

Jonathan Gal-Edd (NASA Goddard Space Flight Center); Curtis C. Fatig (SAIC)

The lack of standardization requires custom ingest scripts for each ground system segment, increasing the cost of the total system. Providing a non-proprietary standard of the database information will allow dissimilar systems to communicate without the need for expensive mission specific database tools and testing of the systems after the database translation. The various ground system components that would benefit from a standardized database are the telemetry and command systems, archives, simulators, and trending tools. The JWST Project has been working with the JPL, CCSDS, and OMG XML personnel to provide the information needed for exchanging database information using XML.

12.0102 Bridging ESA and NASA Worlds: Lessons Learned from the Integration of hifly/SCOS-2000 in NASAs GMSEC

Jean-Pierre Chamoun, Steve Risner, Theresa Beech, Gonzalo Garcia (GMV Space Systems); Inc)

SCOS-2000 is ESA's standard kernel for spacecraft command and control systems. hifly® is a suite of products based on SCOS-2000. NASA's GMSEC defines a standard middleware architecture that can be used by the ground segment of different space missions. The purpose of GMSEC is to easily integrate new flight operations components into Mission Control Centers. This paper explains the lessons learned by GMV during the integration of hifly®/SCOS-2000 in GMSEC. It shows the feasibility of the adaptation of software whose kernel originated from an ESA environment to US missions. It also demonstrates the interoperability of the systems.

12.02 Architecting, Designing, Building, and Testing Successful Ground Systems

Session Organizer: David LaVallee, Johns Hopkins University

12.0201 SCOS-2000 Release 4.0: Multi-mission/Multi-Domain Capabilities in ESA SCOS-2000 MCS Kernel

Rafael Vázquez Osorio, Javier Portela Lemos (GMV S.A); Theresa W. Beech, Gonzalo García Julian, Jean-Pierre Chaumon (GMV Space Systems); Inc)

GMV, leading a European consortium, has recently been responsible for the development of SCOS-2000 Release 4.0, a mature infrastructure Mission Control System managed by the European Space Agency and used in several missions in ESOC and external operators. SCOS-2000 R4.0 addresses three main areas: - Update operating systems and platforms - Upgrade to obtain a truly multi-domain and multi-mission system. - Consolidation: through the re-engineering, harmonization, bug fixing and integration of mission activities SCOS-2000 R4 is the foundation of the future Mission Control System that will be developed for the Galileo constellation.

12.0202 Satellite Test and Operation Procedures Cost Reduction Through Standardization

Jim Cater (ADGA), David Quigley (Rhea System)

This paper describes how Rhea and ADGA are supporting standardization efforts within the ECSS and the OMG to enable the reduction in the costs associated with satellite procedures. These organizations have identified the problems that arise when transferring procedural data between companies involved in building and controlling satellites. These problems are discussed along with the advantages of a standard language, the issues of organizations continuing to use their current infrastructure while adopting the standard; and potential solutions to ease the transition. The advantages of a standards-based approach in a highly regulated environment (eg ITAR) are also discussed.

12.0203 Lessons Learned from Engineering a Multi-Mission Satellite Operations Center

Timothy Esposito, Everett Cary (Emergent Space Technologies, Inc.); Maureen Madden (NASA Goddard Space Flight Center); Dave Bradley, Jeff Parker (Honeywell Technology Solutions, Inc.)

NASA's Small Explorers (SMEX) satellites have surpassed their designed science-lifetimes and their flight operations teams are now facing the challenge of continuing operations with reduced funding. At present, these missions are being reengineered into a fleet-oriented ground system at Goddard Space Flight Center (GSFC). When completed, this ground system will provide command and control of four SMEX missions and will demonstrate fleet automation and control concepts. As a path-finder for future mission consolidation efforts, this ground system will also demonstrate new ground-based technologies that show promise of supporting longer mission lifecycles and simplifying component integration.

12.03 Realizing the Future: Drivers, Challenges, & Concepts for 21st Century Missions

Session Organizer: Theodore Bujewski, The Aerospace Corporation

12.0301 hiflyViews: New Generation Telemetry Visualization

Juan-Carlos Gil, Thomas Morel, Luis Pastor (GMV S.A.); Theresa W. Beech, Gonzalo Garcia, Jean-Pierre Chaumon (GMV Space Systems); Inc)

hiflyViews is the new generation telemetry visualization component of hifly®, GMV's complete monitoring and control solution for satellite fleet operations based on ESA's SCOS-2000 technology. hiflyViews represents a leap forward in satellite telemetry visualization as follows: Flexible data access (real-time, conditional archive retrieval, push/pull, etc), Flexible data presentation (flexible combination of alphanumeric, graphical and synoptic elements), Openness (displays defined via XML, CORBA API, COTS free, portable), Advanced Human-Machine Interface (drag&drop, scaling, zooming, panning, hyperlinks, highly configurable), Pluggable into SCOS-2000 and easy to integrate in any target monitoring and control system. hiflyViews is adequate for all ground segment telemetry visualization needs.

12.0302 Thunderstorm Solar Power Satellite-Issues Dealing with Weather Modification

Bernard J. Eastlund (Eastlund Scientific Enterprises); Lyle M. Jenkins (Jenkins Enterprises)

A revolutionary concept for preventing the formation of tornadoes in a thunderstorm is proposed. Beamed microwave energy from a Thunderstorm Solar Power Satellite (TSPS) could heat rainy downdrafts. Interaction with TSPS has not been simulated. Benefits are lives saved and reduced property damage. Benefits are balanced by safety and risk.

12.0303 Commercial-Off-The-Shelf Workflow Package As a Platform for Mission Planning Data Integration

Alexandre Popov (Canadian Space Agency)

Completing the study series [1, 2, 3] designed to describe and summarize the mission planning data integration experience gathered on MIR and International Space Station (ISS) programs this paper, presents and discusses a pilot implementation of mission planning process (and data) integration approach in terms of an integrated Capability Maturity Model (CMM). To support Mobile Servicing System (MSS) mission operations and meet requirements on the ISS program (ISSP) a number of key processes has been designed as a Web-based workflow software package prototype with inherent features such as access management, e-mail alerts, status monitoring, role/task (re-)assignments, on-line validation, etc.

12.0304 Human Performance Considerations for a Mars Mission

Leslie A. Wickman (Azusa Pacific University)

As humans contemplate further exploration of space, many questions arise regarding the implications of these new endeavors. Spaceflight produces various physiological and psychological effects in humans, which range in time of onset, duration, and recovery. Some of the most serious effects are cardiovascular deconditioning, bone demineralization,

and radiation damage. This paper gives an overview of the human performance issues that must be addressed in preparing for a successful human mission to Mars. Physiological and psychological effects and countermeasures are discussed, as well as crew capabilities and limitations. Human factors design recommendations are given, and crew working volume estimates are considered.

12.04 Enhancing the Mission, Reducing Cost & Risk: Automation, Multimission and Other Solutions

Session Organizer: Kevin Benedict, Air Force Research Lab

12.0401 SmartRings: Advanced Tool for Communications Satellite Payload Reconfiguration

Jean-Pierre Chaumon, Theresa W. Beech, Gonzalo Garcia (GMV Space Systems); Juan-Carlos Gil (GMV S.A.)

The increasing complexity of the payloads of modern communications satellites make it increasingly more difficult to identify a solution that reconfigures the payload to best accommodate the failure of a component and/or new operational constraints. SmartRings provides the operator with the capability to easily reconfigure a communications payload. SmartRings includes a generic reconfiguration algorithm that can be configured to model most modern payloads, taking into account signal degradation parameters. The reconfiguration algorithm is controlled by the payload engineer through the use of constrain and optimization parameters. Current configuration can be downloaded from telemetry automatically. Reconfiguration produces a set of telecommands.

12.0402 MAESTRO: The Versatile Command and Control System Software for Mission Operations and Testing

David Chevers, Darcie Durham, Tom Itchkawich (Orbital Sciences)

Orbital Sciences developed MAESTRO (Mission Adaptive Environment for Spacecraft Test and Real-time Operations) to serve as the command and control system software for flying numerous satellites from our Mission Operations Center (MOC). Although MAESTRO was originally developed for spacecraft operations, it is now used for testing at box, subsystem, and spacecraft levels on nearly all of our missions. The MAESTRO command and telemetry databases are updated in parallel with the spacecraft bus FSW development so they are ready to be used to execute test scripts during Integration and Test (I&T) of both the spacecraft and payload. This approach mitigates significant...

12.0403 Automation of Satellite Requirement Verification

Jim Cater, Dohyung Ahn (ADGA), David Quigley (Rhea System)

Satellite manufacturers demonstration of compliance of their product to the customer's requirements is performed through a comprehensive and extensive testing regime performed throughout construction and integration using a wide variety of test equipment. The process to track the requirement verification status is usually a manual, laborious, repetitive and mundane task; therefore is prone to error. This paper discusses how the MOIS is being enhanced to interoperate with DOORS and ITOS to provide an automated verification environment to develop test procedures associated with the requirements, execute these procedures, automatically update requirement verification status; and generate the requirements verification documentation.

12.0404 Development in Space Projects and the Insurance Market: New Frontiers in Risk Management

Mariagrazia Spada

The liability relationship amongst operators of space vehicles, users contractors and subcontractors is complex. In addition, legal precedents and agreements create uncertainty that may result in unexpected but large exposure to losses. We are speaking about making valuations of the intrinsic economic risks of space market, not in terms of the value of aerospace assets, but rather of their use, that is of their capacity to generate sufficient cash flows to remunerate the subjects involved in the various phases of putting satellites into

orbit. This article provides a broad description of the risks and liability aspects related to the space world.

12.05 Operations Successes and Lessons Learned

Session Organizer: Joseph Vellinga, Lockheed Martin Space Systems Co.

12.0501 The Deep Impact Test Benches: Two Spacecraft, Twice the Fun

Paula J Pingree (Jet Propulsion Laboratory)

The Jet Propulsion Laboratory's Deep Impact (DI) Project was a smashing success with its successful Impact and Flyby Encounter with comet Tempel 1 on July 4, 2005 (UTC). Developing and operating two spacecraft simultaneously required a unique test bench architecture that could support the various configurations of the DI mission. This paper presents an overview of the Deep Impact Test Bench architecture. The process and challenges of operating the test benches, specifically in testing Impactor sequences, are described. Lessons learned from the test bench experience on Deep Impact are shared.

12.0502 Investigation of a Phantom Disturbance Torque Sensed on Space Station during Russian EVAs

Yared Mesfin (The Boeing Company)

This paper describes the investigation, analyses, and tests carried out to determine the source of an unknown "phantom" disturbance torque that was saturating the Control Moment Gyroscopes, causing loss of attitude control of the International Space Station during Russian Extravehicular Activities. Exhaustive flight data analyses, analytic simulations for flight data reconstruction, and an on-orbit "Motionless" test collectively and conclusively show that venting from a heat exchange/cooling sublimator mounted on the backpack of the Russian Orlan spacesuit is the sole source of the disturbance torque.

12.0503 Investigation of the Crew Induced Disturbance to the ISS GN&C System

Nujoud Merancy (The Boeing Company)

Due to the complexity of the International Space Station (ISS), interactions between isolated systems occur requiring interdisciplinary investigations. An example of these relationships is the random low-frequency torque disturbance events exciting a Guidance, Navigation and Control system response. Investigations revealed that the system aliased a 1-Hz structural resonance. Engineering personnel logged the event occurrences and correlated it with crew use of a particular exercise device. The event frequency and magnitude was also affected by vehicle configuration changes. This interaction highlighted the complexity of the ISS and is an excellent example of interdisciplinary engineering investigations that occur on large vehicles.

12.0504 Achieving Operability via the Mission System Paradigm

Fred J. Hammer, Joseph R. Kahr (Jet Propulsion Lab)

Special attention to "Operability" via integrated flight-ground development, can significantly reduce project lifecycle cost and mission risk. A key to achieving operability is the "Mission System Paradigm", in which flight and ground systems are considered components of an integrated, operable "Mission System". This implies some significant changes in the way flight and ground systems are developed. The paper describes these changes, provides rationale, specific examples and implementation recommendations, based on the authors` combined experience.

Track 13: Management, Systems Engineering and Cost

Track Organizer: Charles Leising, Jet Propulsion Laboratory, Caltech
Track Organizer: Todd Mosher, Lockheed Martin Space Systems Co.

13.01 Conceptual Design Capabilities and Tools

Session Organizer: Robert Oberto, Jet Propulsion Laboratory, Caltech

13.0101 Probabilistic Cost, Risk, and Throughput Analysis of Lunar Transportation Architectures

Kristina Alemany, John R. Olds (Georgia Tech)

The Lunar Architecture Stochastic Simulator and Optimizer (LASSO) is a new simulation-based capability, based upon discrete event simulation (DES), for evaluating and optimizing flight element options for lunar transportation architectures. This simulation capability improves the ability to rapidly measure cost, reliability, and schedule impacts of various top-level architecture decisions and impacts of individual elements within a given architecture. Using LASSO, two competing architectures for human lunar exploration are analyzed: an expendable Apollo-style architecture and a next-generation reusable architecture. Nine different launch vehicle combinations are evaluated to determine the optimal architecture and launch option.

13.0102 A Group Decision-Making Interface for Conceptual Design

Gary M. Stump, Mike Yukish, John J. O`Hara (The Applied Research Laboratory)

The ARL Trade Space Visualizer (ATSV) is a multi-dimensional data visualization interface used in early conceptual design to support trade space exploration. This work is focused on extending the ATSV to support a collaborative decision-making environment which consists of multiple participants, where each participant can run a unique ATSV design session. These designs sessions are linked to each other, allowing each participant to share requirements and preference structures with all other participants. Key benefits of this research include the ability to support data exploration and concurrent communication within a design session.

13.0103 Tools to Support Human Factors and Systems Engineering Interactions During Early Analysis

Carroll Thronesbery (S&K Technologies); Jane Malin (NASA/Johnson Space Center); Kritina Holden, Danielle Paige Smith (Lockheed Martin)

We describe an approach and existing software tool support for effective interactions between human factors engineers and systems engineers in early analysis activities during system acquisition. We examine the tasks performed during this stage, emphasizing those tasks where system engineers and human engineers interact, particularly the creation of the Concept of Operations (ConOps) document. We identify commonly used system engineering and human engineering tools and possible gaps in the support of these tasks, the largest of which appears to be creating the ConOps document itself. Finally, we outline our future empirical investigations of tools to support system concept definition.

13.0104 Model-Based Spacecraft and Mission Design for the Evaluation of Technology

Ben S. Bieber, Chester Ong, Jennifer M. Needham, Bing Huo, Angela C. Magee, Craig S. Montuori, Chi Wan Ko, and Craig E. Peterson (Jet Propulsion Laboratory)

In order to meet the future vision of robotic missions, engineers will face intricate mission concepts, new operational approaches, and technologies that have yet to be developed. The Laboratory for Spacecraft and Mission Design (LSMD) at the is developing integrated concurrent models for mass and cost estimations. The purpose of this project is to quantify the infusion of specific technologies where the data would be useful in guiding technology developments leading up to a mission. This paper introduces the design tool to determine the implications of various technologies on the spacecraft system in a collaborative engineering environment...

13.0105 Next-Generation Concurrent Engineering: Developing Models to Complement Point Designs

Elisabeth Morse, Tracy Leavens, Babak Cohanim, Corey Harmon (Jet Propulsion Laboratory); Eric Mahr, Brian Lewis (The Aerospace Corporation)

Concurrent Engineering Design (CED) teams have made routine the rapid development of point designs for space missions. The Jet Propulsion Laboratory's Team X is now evolving into a "next-generation" CED; in addition to a point design, the Team develops a model of the local trade space. The process is a balance between the power of model-developing tools and the creativity of human experts, enabling the development of a variety of trade models for any space mission. This paper reviews the modeling method and its practical implementation in the CED environment. Example results illustrate the benefits of the approach.

13.0106 Orbital Payload Delivery Using Hydrogen and Hydrocarbon Fuelled Scramjet Engines

Matthew Tetlow (The University of Adelaide)

This paper compares the performance of two different launch systems; one with a hydrogen fuelled scramjet stage and one with a hydrocarbon fuelled scramjet stage. The two launch systems are optimized with respect to payload delivery capability and then compared, assuming a fixed launch mass. Results show that a hydrogen powered scramjet launch system outperforms a hydrocarbon powered system due to its higher specific impulse and peak Mach number. While payload mass fractions are shown to be favorable, the high structural requirements of the scramjet imply that reusability is a key characteristic to make them financially viable.

13.02 Design Optimization Tools, Methods, and Processes

Session Organizer: Eric Mahr, The Aerospace Corporation

Session Organizer: Todd Mosher, Lockheed Martin Space Systems Company

13.0201 Problem Formulation for Optimal Array Modeling and Planning

Kar-Ming Cheung, Charles Lee (Jet Propulsion Laboratory); Jeannie Ho (California State University, Fullerton)

To support NASA's vision to increase the Deep Space Network (DSN) communications capability by at least 100 times the current capability of the 70m antennas, the option of large arrays of thousands of 12m antennas is being studied at the Jet Propulsion Laboratory (JPL), and an operational prototype is planned for the 2010 timeframe. The flexibility of dynamically subdividing a large antenna array into smaller array clusters of various sizes to support different concurrent missions and the ability to add or remove antenna elements from an array cluster without interrupting the signal tracking definitely enable new network operation concepts. Yet...

13.03 Management Tools, Methods and Processes

Session Organizer: Jeffery Webster, Jet Propulsion Laboratory, Caltech

13.0301 Experiences in Managing the Prometheus Project

David H. Lehman, Karla B. Clark, Beverly A. Cook, Sarah A. Gavit, Sammy A. Kayali, John C. McKinney, David A. Milkovich, Kim R. Reh, Randall L. Taylor, and John R. Casani (Jet Propulsion Laboratory); Therese Griebel (Glenn Research Center)

Congress authorized NASA's Prometheus Project in February 2003, with the first Prometheus mission slated to explore the icy moons of Jupiter. The Project had two major objectives: (1) to develop a nuclear reactor that would provide unprecedented levels of power and show that it could be processed safely and operated reliably in space for long-duration, deep-space exploration and (2) to explore the three icy moons of Jupiter – Callisto, Ganymede, and Europa – and return science data that would meet the scientific goals as set forth in the Decadal Survey Report of the National Academy of Sciences.

13.0302 Acquisition Strategy and Source Selection for Co-designing a New-Development Spacecraft

Randall L. Taylor (Jet Propulsion Laboratory)

NASA`s Prometheus Project initiated development of a nuclear electric propulsion spacecraft to provide revolutionary capabilities for deep space exploration. An innovative acquisition strategy was implemented, including streamlined proposal evaluation and source selection and a new paradigm for spacecraft development, "co-design." A project team of JPL, NASA Centers, DOE Naval Reactors, and Northrop Grumman successfully completed the spacecraft conceptual design and cost estimation on an accelerated schedule using co-design. This paper summarizes the acquisition strategy and co-design lessons learned, with recommendations for future application.

13.0303 System Architecture Modeling for Technology Portfolio Management using ATLAS

Robert Thompson (Georgia Institute of Technology)

Strategic planners and technology portfolio managers have traditionally relied on consensus-based tools, such as Analytical Hierarchy Process (AHP) and Quality Function Deployment (QFD) in planning the funding of technology development. While useful to a certain extent, these tools are limited in their ability to fully quantify the impact of a technology choice on system mass, system reliability, project schedule, and lifecycle cost. The Advanced Technology Lifecycle Analysis System (ATLAS) aims to provide strategic planners a decision support tool for analyzing technology selections within a Space Exploration Architecture (SEA).

13.0304 Project-Line Interaction: JPLs Matrix

Lynn E. Baroff (NASA (Jet Propulsion Laboratory)

Matrix structures are common in highly technical organizations. The matrix structure is most defined by this characteristic: that most people in the enterprise have two bosses. One resides in the programmatic organizations that make direct contact with the enterprise's customers, and organize and manage work to meet customer expectations. The other boss lives in the line organizations, functional and service organizations that provide the enterprise with capability to accomplish the work. Can programmatic and line organizations really work interdependently, to accomplish their work as a community? What is the secret to making a matrix enterprise actually work?...

13.0305 Improving Inter-Organizational Baseline Alignment in Large Space System Development Programs

Don Greer, Laura Black (Greer Black Company); Richard Adams (The Aerospace Corporation)

This research uses a case study to explore leverage in reducing "disconnects" in baselines across multiple organizations in a large space system development program. Disconnects, latent differences in understanding that negatively affect the program should they remain undetected or unresolved, can jeopardize program cost, schedule, performance, and quality targets. In addition to case-study analysis, we constructed and analyzed a formal dynamic model of communication effectiveness across four organizations that rely on each other for requirements and deliverables. Findings to date refute common beliefs that disconnects result from external stakeholders' requirements changes and that speeding up organizational processes will reduce disconnects.

13.0306 Aligning Technology, Procedures, Operations, Programs, and People to Grow Capacity

Gisele Mohler (Federal Aviation Administration)

The FAA forecasts that by 2015 more than 1 billion people each year will take to the skies in the United States, nearly a third more than today`s number. Central to the agency`s efforts to prepare for the future is the Operational Evolution Plan, which seeks to increase the capacity and efficiency of the National Airspace System. Through the OEP, the FAA commits to initiatives that focus the agency and the aviation community on common, collaborative solutions. The goal has been to increase airspace capacity by 30 percent by 2011, and the OEP is close to declaring success today.

13.0307 The NASA Program Management Tool: A New Vision in Business Intelligence

David G. Bell (Universities Space Research Association); David A. Maluf (NASA Ames); Yuri Gawdiak (NASA Headquarters); Peter Putz (Universities Space Research Association); Keith Swanson (NASA Ames)

This paper describes a novel approach to business intelligence and program management for large technology enterprises like the U.S. National Aeronautics and Space Administration (NASA). Two key distinctions of the approach are that 1) standard business documents are the user interface, and 2) a "schema-less" XML database enables flexible integration of technology information for use by both humans and machines in a highly dynamic environment. The implementation utilizes patent-pending NASA software called the NASA Program Management Tool (PMT) and its underlying "schema-less" XML database called Netmark.

13.0308 Context Based Configuration Management

Yuri Gawdiak (NASA); Mohana Gurram, David Bell, David Maluf (RIACS, Ames Research Center)

The commercial state-of-the-art tools for configuration management systems are very mature for asset, hardware and software development systems. However, strategic management and decisions also have a requirement for configuration management but unfortunately the traditional COTS products are not adequate for those requirements. Given this gap, our team has developed a hybrid tool-suite that marries decision map technology with COTS configuration management workflow and embedded component models ontop of a web based online collaboration system.

13.0309 Advancing the Practice of Systems Engineering at JPL

P. A. `Trisha` Jansma, Ross M. Jones (Jet Propulsion Laboratory)

JPL formed the Systems Engineering Advancement (SEA) Project in order to significantly advance the practice and organizational capabilities of systems engineering on its flight projects and ground support tasks. This paper describes the general approach used and how they addressed the three key aspects of change: people, process and technology. It highlights a list of highly valued personal behaviors of systems engineers, discusses the various products, services and training that were developed, describes the deployment approach used, and concludes with several lessons learned. Their scope included all three dimensions of a project – the full life-cycle, depth, and technical scope.

13.04 Risk Management

Session Organizer: Melinda Gallo, Northrop Grumman Mission Systems
Session Organizer: Mona Witkowski, Jet Propulsion Laboratory, Caltech

13.0401 Vulnerabilities, Influences and Interaction Paths: Failure Data for Integrated System Risk Analysis

Jane T. Malin (NASA Johnson Space Center), Land Fleming (MEI Technologies)

We describe analysis methods for identifying and analyzing cross-subsystem interaction risks from subsystem connectivity information. These methods identify entities that can pose a hazard to a function if they can be propagated from the hazard source to the vulnerable function. The analysis method can assess combined impacts of multiple disabling influences on a vulnerable function. The analysis method also uses numerical estimates of hazard strength to calculate cumulative measures of impact severity. These methods to increase coverage of risk analysis can support design of more dependable and diagnosable systems and promote better communication among subsystem designers about risk.

13.0402 The Near-Miss Bias in Decision Making

Robin L. Dillon (Georgetown University), Edward W. Rogers (NASA Goddard Space Flight Center), Catherine H. Tinsley (Georgetown University)

When there is a technical failure, most organizations are good at identifying the technical cause and learning not to repeat that same mistake. However, it is more difficult to learn

from near-misses and lucky successes (i.e. situations where a technical failure does not occur but nearly did). This research shows that managers whose decisions ended in a failure were perceived as significantly less competent, as having made poorer decisions, and as less deserving of promotions than managers that made the same decisions but whose project outcomes were either a success or a near-miss.

13.0403 Improving the Application of Risk Management

Karl Davey (Strategic Thought Group - Active Risk Manager)

Having 'on paper' a good risk management process is not enough to ensure success, it is a common fact that people will make or break a process. Developing synergy between the risk process, and people is key to successful risk management. This presentation will explore the problems faced, and the solutions necessary to ensure a `Real` and `Effective` contribution to the management of risk. Using examples from organisations currently implementing risk management this presentation will highlight techniques to gain buyin and commitment with the vision of moving from a 'Name and Blame' to a 'Name and Gain' risk management culture.

13.0404 Risk Assessment Practices at NASA: Studies of Design and Review Methods

Lawrence Chao (Intel Corporation), Irem Tumer (NASA Ames)

This report describes a number of design and review activities observed at NASA for risk identification, assessment, and management. The NASA life-cycle is centered around the experience of its scientists, engineers, and managers, and the checks-and-balances are primarily instituted through a number of programmatic and technical reviews but also workshops and design tools. This paper explores the project development on both a full mission level as well as an accelerated design project to better demonstrate the range of methods used to identify and manage risk in NASA missions. With better understanding of not only the execution but motivation for the...

13.05 System Engineering Processes, Modeling and Verification

Session Organizer: Bruce Wilson, The Boeing Company
Session Organizer: John Baker, Jet Propulsion Laboratory, Caltech

13.0501 Simulation Based Acquisition for the Rest of Us

Michael S Anderson, Puja Gupta, Michelle W Chen (The Boeing Company)

Simulation Based Acquisition (SBA) enables robust, collaborative, and integrated use of modeling and simulation (M&S) technology across acquisition phases. Extending the concept of Integrated Process and Product Development (IPPD), SBA promises to reduce cost and risk while promoting higher product quality. SBA is characterized by program-wide collaboration, a single authoritative source of system and program data, standardized tools and processes, and integrated M&S for system architecture assessment, design configuration effectiveness analysis, and virtual prototype use during system integration, test and evaluation. Any program will benefit from implementation of one or more of these SBA concepts.

13.0502 Simulated Moon, Mars, and Beyond

Thomas K. Cummings (The Boeing Company)

NASA plans on returning to the moon and then onto Mars as part of their Vision for Space Exploration (VSE). Integrated Modeling and Simulation (IM&S) is critical to the success of that effort. Industry has performed IM&S of other large scale complex programs such as Ground-based Midcourse Defense and Future Combact Systems that provide valuable lessons learned applicable to NASA`s VSE initiative.

13.0503 Creating a Tool Independent System Engineering Environment

James E. Pederson (The Boeing Company)

Specialized system engineering tools, although capable at supporting specific tasks or functions, have limited use in most organizations and don't clearly fit into a broader project

data architecture. Attempts by either the tool users or developers to integrate applications outside of a bundled tool set have generally been limited to various forms of data import which creates recurring manual administrative effort and related configuration management problems by having data in multiple places. This paper will address issues and challenges associated with current methods of integrating systems engineering tools and data.

13.0504 ANSI/AIAA Guide for Estimating Spacecraft Systems Contingencies Applied to the NASA GLAST Mission

Norman Rioux (NASA Goddard Space Flight Center)

An assessment is conducted of the mass and power contingency trends experienced by NASA's GLAST Mission from Bid through CDR with respect to the ANSI/AIAA Guide for Estimating and Budgeting Weight and Power Contingencies for Spacecraft Systems. The GLAST Mission has allocated and managed mass and power contingencies for the spacecraft bus and each of the scientific instruments based on application of the ANSI/AIAA Guide. The correlation of the GLAST experience with the Guide is analyzed and suggestions are offered to potential users of the Guide for increasing the effectiveness of their application of it on other missions.

13.0505 Automated Design of Spacecraft Power Subsystems

Richard J. Terrile, Mark Kordon, Dan Mandutianu, Jose Salcedo, Eric Wood, Mona Hashemi (Jet Propulsion Lab)

We demonstrate the feasibility, application and advantage of using evolutionary computation techniques for the early design search and optimization of space systems. Our software automatically generates design options for selecting and sizing power elements based on the space system's anticipated performance in the simulated environment. Initial Activity plans from two actual JPL missions, Mars Exploration Rovers (MER) and Deep Impact (DI) are used to test the software. Our results have shown human-competitive advantages by generating credible design concepts much faster than humans are able to and without the need for expert initial designs.

13.0506 Validation (not just Verification) of Deep Space Missions

Riley M. Duren (Jet Propulsion Laboratory)

The definition "Verification proves the design is right; validation proves it is the right design" is rather vague. While Verification is a reasonably well standardized systems engineering process, Validation is a far more abstract concept and the rigor and scope applied to it varies widely. This is reflected in the findings in recent NASA Mishap Reports, in which shortfalls in Validation were cited as contributing-factors in catastrophic mission loss. Another strong motivator is a realization that the rapid growth in complexity of deep-space missions (particularly Planetary Landers and Space Observatories) is placing increasing demands to "get it right" with Validation.

13.06 Cost Tools, Methods and Processes

Session Organizer: Robert Bitten, The Aerospace Corporation

13.0601 Integrating Three Level 2 CMMI Process Areas: Closing the Loop on Software Project Management

Michael A. Ross (Galorath Inc.)

Performance Measurement has become a best practice for monitoring and controlling software projects. It employs command/feedback principals to increase the probability that a project's actual performance matches its planned performance. Experience with this process suggests an opportunity for process improvement by including established estimation methodology and algorithms as part of the forecasting and re-baselining activities. This paper proposes a process called Parametric Project Monitoring and Control (PPMC) whereby accepted algorithms currently used for software cost and schedule estimation are incorporated into the forecasting and re-baselining processes to yield a more-realistic time-range prediction of the project's cost and duration.

13.0602 Financial Catscans and Time

Douglas K. Howarth (Lockheed Martin Aeronautics Company)

This paper demonstrates that markets (as for business aircraft) exhibit Value Estimating Relationships (VERs), which exist in spaces which share exactly one axis with their corresponding Aggregate Demand Curves, that of price or currency. In any viable market, the outputs of VERs, Cost Estimating Relationships (CERs) and Aggregate Demand Curves, along with relevant technical, physical and legal constraints form Financial Opportunity Spaces (FOSs), which change over time. Once Financial Opportunity Spaces are determined, section cuts through them provide two-dimensional Financial Catscans. Financial Catscans direct financially optimized entry points into marketplaces, as well as price, value and cost attributes.

13.0603 Do Higher Cost Reserve Levels for Space Science Missions Ensure Good Cost Performance?

Mark Jacobs, Shawn Hayes (Science Applications International Corporation)

Recent efforts to improve cost performance for space science missions have included a fairly significant minimum cost reserve level. However, many projects that start with a strong reserve posture appear to experience as much or more cost growth than projects that have begun with less reserves. This study investigates cost reserves and performance for several space science missions and attempts to identify the most significant causes for cost growth and reserve expenditures and provides suggestions for improvement. Initial findings suggest more emphasis on careful front-end planning and a conservative base estimate may enable better cost performance with lower reserve levels.

Track 14: Government Plans, Policies, and Education

Track Organizer: Mel Montemerlo, NASA Headquarters

14.01 PANEL: Developing the 21st Century Space Engineering Workforce

Session Organizer: Bruce Gardner, The Aerospace Corporation

Summary: TBD

14.02 PANEL: The History of Robotics at the Jet Propulsion Lab

Chair - Mel Montemerlo (NASA Headquarters)
Featured Panelist - Brian Wilcox, JPL

Summary: This panel will begin with a brief overview of the history of robotics. This will be a pictorial review of major developments in the field from the development of the term "robot" to the present time. This introduction will place the featured talk in context. Brian Wilcox will describe the history of robotics at the Jet Propulsion Laboratory from the 1960s to the present. Brian brings a unique perspective to this topic, not only because he has spent his career at JPL in the field of robotics, but because his father was also an innovator in this field. Brian's talk will include end with information on the two current Mars rovers and with some prognostications about future directions.

14.03 PANEL: What is the Future of "Planet Finding"

Chair: Michael Devirian (Jet Propulsion Laboratory)
Panelist: Jennifer Dooley (Jet Propulsion Laboratory)
Summary: Surprisingly, the debate not only about whether we are at the center of the universe or an incidental element in it, but also whether we are alone or simply one tribe of humans on one little planet in a universe teeming with life was engaged by ancient Greeks and renaissance monks. It has taken 2500 years to move the debate from theory to observation. Ten years ago, observations by a Swiss team confirmed the first extra-solar planets. Today, over 150 "exo-planets" of varying sizes, mostly quite large, have been confirmed. Various teams have been working since the mid-'80s to develop the technologies that will enable the first direct detections of planets that are "Earth-like", and in the habitable zone around neighboring stars. The space missions that will accomplish these feats are well along in planning. In 2004, the President's Vision for Space Exploration called for "advanced telescope searches for Earth-like planets and habitable environments around other stars." This panel will discuss the science, technology, missions and policy issues surrounding NASA's Navigator Program: Exploring New Worlds that will carry out these missions to answer the question "Are We Alone?".

14.06 PANEL: International developments in Space Robotics on the ISS Program and Beyond

Chair: Alexandre Popov, Canadian Space Agency
Summary: The panel program is currently divided into primary application areas, which are robotic planetary exploration and on-orbit servicing including robotics on the International Space Station (ISS). The panel will provide a review on-going missions as well as planned ones together with desired capabilities and technology requirements, which emerge from the missions. The panel also provides examples of technologies, which may have important relevance to future missions from different perspectives (e.g. tele-presence and remote control for operations on and maintenance of International Space Station; design, development and support of autonomous space robotic systems, and space robotics technology roadmaps). The panel of experts will also discuss space robotics goals, concepts and issues. The following three groups of space robotics missions has been planned to discuss on the panel. a) Planetary exploration missions (in largely Moon-to-Mars program); b)Robotics on ISS; c) On-Orbit Flight Experiments (in largely free-flying servicing robot). Reducing cost, while simultaneously enabling new and exciting capabilities in planetary exploration missions, is one of major goals of the next-generation of the missions. Enabling technologies for cost reduction include miniaturization of robots, autonomous

robotics, and streamlined operations. The panelists will describe their recent accomplishments and technology development plans to enable ever more important use of robotic systems in light of the current international plans for space missions. Among accomplishments made the following will be presented: ground controlled robotic inspection of International Space Station; monitoring of extravehicular activity and docking to the ISS; inspection capabilities for detection of gas leaks, temperature changes, and small cracks using additional sensors; motion guides and sensor based collision detection and avoidance technology to enable robot operations in constrained areas such as Space Station truss. It is expected that experts from USA, Canada, Japan and Europe will deliver their presentations followed by discussion with the audience.

14.09 PANEL: Spacecraft Autonomy: New Directions for the Future

Chair: Steve Chien, Jet Propulsion Laboratory, Caltech

Summary: NASA began research and development in spacecraft autonomy in 1985. At that time, almost all of the NASA Centers developed groups of experts in artificial intelligence to apply these new techniques to increasing the capability and autonomy of spacecraft. Early applications included the use of rule based systems in mission control for the Space Shuttle, and automated scheduling at Kennedy for Shuttle refurbishment. Later NASA's DS-1 satellite contained an experiment called "Remote Agent". This panel will explore the current and future directions being taken both for manned and unmanned spacecraft.

14.12 PANEL: Beyond Einstein

Chair: : Louis Barbier, NASA / Goddard Space Flight Center

This panel will overview of the NASA Universe Division Beyond Einstein program. The Beyond Einstein program consists of a series of exploratory missions to investigate the most important and pressing problems in modern-day astrophysics – including searches for Dark Energy and studies of the earliest times in the universe, during the inflationary period after the Big Bang. A variety of new technologies are being developed both in the science instrumentation these missions will use and in the spacecraft that will carry those instruments.

14.89 Science and Engineering Education

Session Organizer: Bruce Gardner, The Aerospace Corporation

14.8901 A Solar-Power Design Competition Inspiring Student Interest in Engineering

Eric MacDonald, Scott Starks, Sally Blake (The University of Texas at El Paso)

This paper presents an educational outreach activity that utilizes a design competition to inspire pre college students to continue their education at the university-level and enter into degree programs relating to science, engineering or mathematics. The competition was one of many activities included in TexPREP (Texas Prefreshmen Engineering Program), which involves high-achieving middle and high school students from the El Paso, Texas region in an academically-intense eight-week educational program.

[1] The basic information for the Digest is supplied by the authors when submitting their final papers.
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