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PRESIDENT’S MESSAGE

FEATURES

Deep Space Astrobiology – Exoplanet Explorer Spacecraft and Tools to Explore Other Worlds

Enabling technologies for deep space astrobiology will transform our scientific orientation and foster better understanding of Earth’s place in the universe and our significance as a civilization.
by Eugene F. Lally

The Death of Rocket Science in the 21st Century

As we enter the 21st century, modern rocket science as an engineering discipline is at a standstill towards the next paradigm shift in how humans get to space. This can be remedied through the development of a new discipline called space propulsion science.
by Glen A. Robertson and Darryl W. Webb

The Radio Aurora Explorer

Built by University of Michigan students and faculty, the Radio Aurora Explorer (RAX) is the first National Science Foundation sponsored satellite mission.
by Allison Craddock and James Cutler

NOTES ON A NEW BOOK

Space Exploration and Astronaut Safety
Reviewed by Mark Williamson

CALL FOR PAPERS

21st AAS/AIAA Space Flight Mechanics Meeting

AAS NEWS

2010 National Conference

UPCOMING EVENTS

ON THE COVER

FRONT: A Prominence eruption as seen by the Solar Dynamics Observatory shortly after the payload was activated. The emission line is from singly ionized Helium, and corresponds to a temperature of about 50,000 degrees Celsius. (Source: NASA)

BACK: Inset: A view of the IKAROS spacecraft with its solar sail deployed. IKAROS is the world’s first spacecraft to use a solar sail as a main source of spacecraft propulsion. Background: A view of the sample return portion of the HAYABUSA spacecraft, which is hoped to contain pieces of near-Earth asteroid 25143 Itokawa, another world first. (Source: JAXA)

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3
4
9
15
17
18
20
21
23

As a follow-up to my review of the AAS Spaceflight Mechanics and Guidance and Control committees, I want to introduce another vital AAS group that may not be well known to all members – the AAS History Committee. The History Committee (HC) was formed in 1978 with Eugene Emme, NASA’s first historian, as chair. Its original purpose was to “serve as a focal point for the historical matters in the AAS, to support the Editor of the AAS History Series, and to recommend and expedite actions serving the historical needs of American astronautics.” The size and scope of the committee has expanded over the years, with current members drawn from academia, industry and the government sector. Although many hold professional degrees in history, other degrees represented include engineering, English, and psychology. Michael Ciancone has served as Chair since 2001.

The AAS History Committee was established to stimulate historical research in and teaching, publication, and preservation of the history of astronautics, while encouraging interest and scholarship in and appreciation of the history of astronautics.

Activities of the Committee include, but are not limited to, recommending topics for and coordination of and participation in meetings addressing historical subjects; encouraging publication papers, articles, and books on topics in the history of astronautics; and providing recognition and prizes for significant historical achievements in astronautics.

In addition the Committee collaborates with other historically oriented groups and organizations, including the history groups of the American Institute of Aeronautics and Astronautics (AIAA), the International Academy of Astronautics (IAA), the National Aeronautics and Space Administration (NASA), the European Space Agency (ESA), the Smithsonian Institution, the New Mexico Museum of Space History at Alamogordo, the Huntington Museum, and others.

A special subcommittee reviews new books on topics in astronautics and selects recipients of the annual Emme Award for Astronautical Literature, named after its first chair, which recognizes outstanding publications that advance public understanding of the effects of astronautics on society. And, the HC has joined with the VP Education to jointly manage a new award, affectionately referred to as the Emme Junior, which recognizes outstanding books that targets the youth audience. The Committee also collaborates closely with the IAA History Study Group in the editing and publication of the proceedings of IAA Historical Symposia in the AAS History Series. In addition, the HC coordinates the review by Committee members of books of potential interest to the AAS membership in general and the spaceflight history community in particular.

The HC has provided leadership and editorial support over the past several years in the development of an encyclopedia of spaceflight history with ABC-CLIO publishers. This work, which is scheduled for release late this summer, is likely to become a standard reference in the field. Stephen Johnson of the HC has patiently and diligently served as the General Editor for the encyclopedia, while other members of the committee have supported as Area Editors and authors.

The HC also provides editorial support for the publication of the AAS History Series through Univelt publishers. Each volume contains the papers presented annually during the IAA History Symposia held in conjunction with the International Astronautical Congress (IAC). Rick Sturdevant assumed the role of Series Editor in 2008 following the long-time stewardship of Don Elder.

In 2006, the HC introduced Explorer, a periodic newsletter. Under the editorial leadership of Tim Chamberlin, this newsletter has provided visually pleasing and unique information of historical interest. One item in particular that has attracted interest beyond the AAS realm is its annual list of astronautical titles that are published each year.

If the HC’s activities sound of interest to you or, if you’d just like more information, please contact Michael Ciancone at michael.l.ciancone@nasa.gov. You can also access the current and past issues of Explorer on the AAS web site.

I hope you’re having an enjoyable summer. AAS has an exciting fall ahead with the Von Braun Symposium scheduled for October 25-27 in Huntsville, Alabama, and our national conference scheduled for November 16-17 in Cape Canaveral, Florida – focused on the International Space Station. I hope you will consider joining us at one or both events. More details are available at www.astronautical.org.

AAS – Advancing All Space

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PRESIDENT’S MESSAGE
Deep Space Astrobiology –

Exoplanet Explorer Spacecraft and Tools to Explore Other Worlds

by Eugene F. Lally

The journey of space exploration may never end. Under current budgetary and political constraints, space exploration can best be served using more cost effective unmanned craft rather than manned spacecraft missions. The glamour and excitement of landing men on the Moon and planets comes at a huge, unrealistic cost and the resulting science learned is limited only to our own solar system. It is time to move in a different direction.

Astrobiology is the study of understanding the origin of the building blocks of life-forms, how inorganic and organic components combine and evolve to create life. The field also studies how life affects, and is affected by, the environment from which it arose. Locations beside Planet Earth where life may be evolving or exist, considering the time frame determined by distance from Earth are also considered. A large array of scientific and engineering disciplines needed to pursue this endeavor will be stimulated to reach beyond their present capabilities and move on to new learning curves.

Detection of breakthrough information across interstellar space is upon us. We are on the threshold of using our technological imagination to conceive creative approaches for remote sensing from a spacecraft to advance astrobiology. Inspiring scientific discoveries are expected from instruments on unmanned spacecraft focused on exploring exoplanet atmospheres and their parent stars’ surroundings. Such instruments are capable of remotely investigating newly discovered exoplanets of Earth-like size, orbiting in habitable zones around their parent stars. A new, broader range of science will be explored at an acceptable cost.

A new generation of exploratory concepts is offered to stimulate the space program and the public to levels not experienced since Kennedy’s Camelot era. Uplifting non-political attitudes will help bring pride and positive thinking back, through the creative ideas of scientists and astrobiologists. There was an exhilarating feeling of hope and accomplishment in the United States with the decision to compete against the Russians after their Sputnik artificial satellite’s success in 1957. This time, that feeling will not be driven by the embarrassment of being upstaged by a totalitarian nation, but will be motivated by scientific exploration, technology development and the improvement of our knowledge base to advance our specie and our industrial prowess.

Earth-centric thinking

Until the 1500s, people believed the Earth was at the center of the universe and the solar system, with the Sun and everything else revolving around us. Copernicus and Kepler determined the orbital laws of the planets, disproving that theory. Their discoveries made them unpopular with Earth-centric people who were humiliated by the discovery. Their work established our initial understanding of the correct structure of our solar system. Now, with availability of newly conceived and designed instruments for spacecraft, we can reach out remotely to deep space and jump onto a new learning curve.

Scientists and astrobiologists determined that distant stars are suns and like our Sun can provide energy to orbiting planets, if any are present. The Big Bang theory posited that everything began 13.7 billion years ago. The Earth is considered 4.5 billion years old, and life-forms appeared on the surface after one billion years. Discoveries about our solar system started in 1609 when Galileo viewed four moons of Jupiter and craters on the Moon using the newly invented telescope. Discoveries accelerated and in 1930, when astronomer Clyde Tombaugh at the Lowell Observatory in Flagstaff, AZ found Pluto, the ninth and last planet discovered in our solar system. Pluto was downgraded in 2006 to dwarf-planet status when astronomy advanced and discovered other...
celestial bodies in our solar system similar in size to Pluto and found that refinement of a planet’s definition was needed.

Radio astronomy came to be in the 1930s and other discoveries became available. As with these past revelations including discoveries beginning in the 1960s from Earth-satellites, planetary spacecraft flybys, orbiters and landers, we are again on a threshold of countless revelations about the make-up of our universe. It is up to us to break through this threshold and accelerate our learning to better ourselves through scientific knowledge.

Many people believed the planets in our solar system were the only planets in the universe until 1995, when astronomers confirmed the first “exoplanet,” the name describing a planet orbiting a star other than our Sun. Ground based telescopes initially discovered giant planets, beginning a new era of scientific endeavour.

The question, “Are there other planets in addition to those in our solar system?” has been answered the past fifteen years with a resounding “Yes.” Ground-based optical telescopes improved and observed Doppler shifts in star spectra due to the presence of planets causing stars to wobble. Ground telescopes also detected star wobbles through long term tracking of stars’ precise locations. When these were plotted, they also provided proof of orbiting planets. Such observations led to discovering several hundred Jupiter-scale gas giant planets orbiting their parent stars. These discoveries proved the feasibility of detecting planets orbiting stars other than our Sun. This capability is technically exciting and advances us to another question, “Are we alone?” The question was first proposed by astronomer and astrophysicist Dr. Frank Drake in 1960. This led to his Drake Equation, an attempt to estimate the number of extraterrestrial civilizations in our Milky Way galaxy that we could come in contact with through detecting their intelligently produced electromagnetic signals. He also introduced the Search for Extraterrestrial Intelligence (SETI Institute) concept, using a large diameter radio astronomy receiver followed by smaller diameter multiple receivers using interferometry.

**Exploring Exoplanet Atmospheres**

The serious undertaking to search for exoplanets, analyze their atmospheres, and identify those with conditions suitable for life-forms with the ultimate objective to locate intelligent civilizations beyond our solar system is now available for deep space astrobiology research using optical techniques. This will drive our space research in a new direction. Profound new understanding of physical conditions and history of exoplanets and their evolutionary building blocks will be derived.

Smaller Earth-size planets more suitable to supporting life-forms than the giant planets already discovered are not able to be detected with ground-based methods due to inherent limitations of equipment and looking through Earth’s atmosphere. Detailed information using infrared characterization of exoplanets which cannot be expected from ground-based observations is possible from space. Fortunately, a breakthrough has occurred and is available from NASA’s Kepler spacecraft mission launched March 2009. This spacecraft provides tools to detect smaller planets that offer a higher probability of supporting life-forms.

The relationship of planet size and distance from its parent star can be determined to find Earth-size planets located in habitable zones. The presence of suitable atmospheric constituents to support life-forms on these planets offers one new exploratory area. Spectroscopy technology will investigate the atmospheric properties of such exoplanets including looking for biological markers.

Kepler spacecraft hardware includes a digital camera focal plane operating as a photometer in the largest spaceborne telescope constructed to date. It stares at a selected group of stars from the pristine environment of space. It will detect planets transiting these stars, passing in front of the star and blocking a small amount of the star’s light. New high dynamic range instrumentation allows monitoring exoplanets’ minute reduction in the light intensity transmitted by the parent star when occulted to determine the presence of exoplanets. Placing such a photometer in space beyond the optically disturbing atmosphere of Earth permits a faster rate of discovery of Earth-type planets. The lineage of viewing planets and other celestial bodies using a digital camera onboard spacecraft first was proposed in my 1961 paper. “Mosaic Guidance for Interplanetary Travel.” This concept was called AutoNav and adapted by NASA to

Exoplanet Explorer Spacecraft (Illustrated by Douglas Cali) (Image courtesy of Eugene Lally)
reduce program costs of unmanned planetary spacecraft missions. It also was applied to the telescope on the Kepler spacecraft and for instruments on future spacecraft as proposed here.

The progression of technical accomplishments to realize “Deep Space Astrobiology” consists of the following:
1. Detect planets orbiting stars
2. Determine planets’ distance from their parent stars
3. Determine planet’s size and mass
4. Identify Earth-size planets
5. Determine planets in potentially habitable zones
6. Determine atmospheric characteristics of those planets using infrared spectroscopy from spacecraft
7. Determine probability of life-forms on those planets by searching for biological and techno markers
8. Team up with radio astronomy techniques (SETI) on these selected exoplanets and combine electromagnetic signals to the search for intelligent civilizations

Earth-size exoplanets discovered in habitable zones of stars are more likely to develop life-forms because of more favorable temperature, atmospheric constituents, pressure, weather conditions and gravity. Follow-on programs after the Kepler spacecraft include the James Webb Space Telescope (JWST), currently scheduled for a 2014 launch. It will encourage the next step to examine exoplanet atmospheres and investigate their age and history. Placing instruments in space rather than at ground based locations increases the availability of detector performance needed to analyze exoplanet atmospheres. The James Webb Space Telescope and the next generation of specialized instruments proposed here will be capable of analysis of exoplanet atmospheric constituents.

We proved the feasibility of using spacecraft to identify planets containing life by studying a spectrum of the Earth taken from space by the Galileo probe looking back at Earth. The detection of a large amount of oxygen and the simultaneous presence of methane traces in the Earth’s spectrum theoretically suggested biological activities thus offering a confirmed point for modeling. Research studies will be conducted to develop models to understand how observed atmospheric constituents translate physically and chemically to exoplanet conditions. A framework will be developed from observed atmosphere constituents to develop strategies for rating detected biomarkers on exoplanets.

We will also study the material around stars having planets. How building blocks of planets are assembled will be researched. To trace the origin of the planet Earth and evolution of its life-forms, we must know whether planetary systems form in place, or whether they form elsewhere outside that system and are drawn into closer orbits as the system stabilizes.

A new spacecraft with new tools to explore other potential worlds

To accomplish these investigations a new class of spacecraft with specialized instruments is needed. The Exoplanet Explorer (E²) spacecraft is proposed. A conceptual spacecraft artist’s illustration is presented. This program will be accomplished for modest cost and low technical risk with state-of-the-art spacecraft technology and proven spectroscopy telescope design. Multiple exoplanets will be observed simultaneously using a multi-shutter assembly to increase the program’s cost effectiveness. A three-year primary mission will characterize the atmospheres of Earth-sized exoplanets in habitable zones. A supply of superfluid liquid helium housed in a Dewar will be available for infrared detectors needing the coldest temperature for the primary mission. A hydride sorption cooler will act as a long term cryogenic cooler boost, using liquid hydrogen for the refrigerant fluid. The telescope outer shell will face no heat loads and be protected by the spacecraft’s heat shield, and be passively cooled to 25K by facing deep space. An extended secondary mission, five years or longer, will investigate material surrounding stars and perform a deep space survey at wavelengths not previously covered. The latter will provide chemical diagnoses of selected celestial objects to increase mission cost effectiveness and mission duration using combined active and passive cryogenic cooling of infrared detectors.

Atmospheric information obtained will include chemical composition of larger exoplanets and surface characteristics of smaller rocky exoplanets with formation history explored. An onboard calibration scheme will compare spectra of different orbital phase angles of exoplanets at useable signal to noise ratios. This will allow day and night side differences of exoplanet atmospheric conditions and chemistry to be investigated.

The Exoplanet Explorer spacecraft will be launched on a two month trajectory to the L2 Lagrangian Point. This is uniquely suitable to locate a spacecraft requiring cryogenic cooling and offers the most cost effective approach to shadow it from the Sun and Earth’s infrared emissions. The Earth will shadow 85% of the Sun’s radiation; no other orbit selection can provide any shadowing. The telescope’s infrared detectors require low temperature and can best be served with minimal impact on spacecraft design and cost at the L2 location. Here, the spacecraft is locked into a solar orbit on a line connecting the Sun and Earth and at the L2 point, which lies 1.5 million km further from Earth on that line orbiting in synchrony with the Earth’s orbit. Normally an object orbiting at this distance from the Sun would lag behind the Earth’s orbit. At the L2 point, the combined gravitational forces of the Sun and Earth uniquely capture the spacecraft.

The spacecraft and telescope will be shielded from the aligned Sun and Earth’s heat sources by a double lightweight multi-layer heat shield mounted on the bottom of the spacecraft facing the emission sources. The shield will use multiple layers of thin, lightweight, low solar absorption metalized polyester to deflect heat sources. The 12 meter by 12 meter square thermal shield will deploy and unfurl from its stowed location after launch. While the L2 point uniquely provides the necessary shielding from the Sun’s thermal radiation, its absence thereby precludes using solar cells.
for electrical power. A radioisotope thermoelectric generator (RTG), a spacecraft electrical power source proven reliable since the 1960s, will supply a steady level of power well beyond the duration of the mission. It is stowed on a boom which moves after launch, placing the RTG away from the spacecraft in the direction behind the sun shield in order to minimize thermal load feedback.

As exoplanets are discovered, our scientific curiosity will move us to investigate their atmosphere. The spectrum of light received from the atmospheres will be analyzed to identify composition. A star is much larger in size and brighter than any exoplanet, making spectral analysis of the planet’s atmosphere difficult. A halo effect surrounding the star obscures faint planets orbiting the star, preventing direct spectral analysis of the light output of the exoplanet’s atmosphere. New techniques are available to work around that.

A diffraction-limited image is desired, as it is free of the effects of looking through the Earth’s atmosphere and other sources of imaging error. Adaptive optics have provided various levels of improvement for ground based telescopes. Ground-based investigations of exoplanets are biased toward discovering large planets orbiting close to their parent star. This technique has been improved during the past ten years, and new larger ground telescopes are under construction to refine this process.

A better solution as proposed here is to place the telescope in space on a spacecraft platform such as Exoplanet Explorer with stable and accurate pointing capability. The Hubble Space Telescope took advantage of this approach, and the field of astronomy was advanced far beyond what was anticipated. The Exoplanet Explorer also will cause changes in a broad base of scientific disciplines and will allow astrobiologists to remotely take their discipline into deep space.

Spectroscopy – the key to discoveries

One spectroscopy approach using occulting masks will enable observations of exoplanet spectra in habitable zones by blocking out the parent star and the halo effect for direct viewing of exoplanet atmospheres. Another approach first records the combined spectrum of the star and exoplanet. After the planet transits in its orbit behind the star’s disc, a second spectrum is recorded of the star only, which is subtracted from the combined spectrum to leave the emission spectrum of the planet only. A breakdown of this light into wavelength components will disclose the constituent molecules of the planet’s atmosphere. The atmosphere’s chemistry is further analyzed for organic molecule biomarkers leading to considerations of potential life-form presence.

The Exoplanet Explorer will investigate atmospheres’ potential of chemical evolution and where it is in the cycle. The conditions of primitive Earth were thought to have favored chemical reactions. Starting with inorganic compounds and with the

help of volcanic activities and electrical sparking from atmospheric lightning or ultraviolet light, they synthesized into organic compounds leading to the origin-of-life theory for the Earth. This theory is equally applicable to exoplanets. These hypothetical conditions have been simulated in laboratory experiments such as the Miller-Urey experiment and many others. While early chemistry of the Earth’s atmosphere and that of exoplanets are unknown, a variety of probable models have produced organic compounds in laboratories starting with inorganic precursors as expected on evolving exoplanets.

Spectroscopy instruments on the Exoplanet Explorer spacecraft will search for water, methane, ammonia and hydrogen on exoplanets with habitable zone conditions. Eventually, carbon forms lead to amino acids that are used to make proteins in living cells. When all available atmospheric constituent data is processed, each exoplanet will be graded and a “Lally Life-form Probability” rating determined.

In addition to searching for biomarkers, techno-markers will be investigated which are special atmospheric features not explained by complex organic chemistry. They are created from technological activities of inhabitants that enter the atmosphere. For example, Carbon Fluoro Compounds (CFC) generated by industrial activities on Earth have produced atmospheric damage to our ozone layer. This is an example of a phenomenon a civilization can produce that absorbs infrared light at tell-tale wavelengths, allowing detection from a remote spacecraft. SETI Institute listens for intelligence-based radio signals that may deliberately have been transmitted toward us on a narrow beam from exoplanets. Such broadcasts probably would be of short duration by the nature of the amount of transmission time devoted by extraterrestrials, therefore offering a low probability of ever being detected on Earth. This has been the case since our observations began in 1960, with no confirmed received transmissions to date. The United States in 1974 directed radio signals into space that described basic Earth chemistry, our planet’s location and the technical specifications of the transmitting system used at Arecibo, Puerto Rico for only 28 minutes. In 1999, Russia duplicated the Arecibo experiment also for a short duration. This notes that our attention span for such matters is extremely short, as probably would be for other civilizations transmitting direct signals outward.

Chemical constituents related to biomarkers as well as chemical techno-markers from exoplanets would be available for detection by a spaceborne spectrometer over a long and steady-state period, and be more reliably detected and interpreted. When biomarkers are found with high life-form probability, SETI Institute could concentrate on those exoplanets, providing a combined investigation of chemical-optical and electromagnetic sources.

It should be noted that the definition regarding the search for life-forms at this juncture is “life as we know it.” We understand that microbial life exists in extreme ranges of temperature, pressure, salinity and pH. It also survives intense radiation, vacuum, darkness and desiccation. This suggests that “life as we do not know it” is able to thrive under conditions we do not yet understand. Until we better understand the chemistry to support such extremophiles and their related atmospheric chemistry, our work will simply assume “life as we know it.” This scope is broad enough to begin our new challenge of exoplanet exploration using deep space astrobionics techniques to view and determine atmospheric chemical constituents. When one begins to think about this challenge, new questions and ideas flow from imaginative thinking. Harnessing this creative energy will move us toward a new learning curve to better understand Earth’s place in the universe and our significance as a civilization. Our scientific orientation will be transformed.

As a pioneer in the space race, Eugene F. Lally published initial design concepts of spacecraft to explore the Moon, Mars, Jupiter, Saturn, comets, and asteroids at the Jet Propulsion Laboratory. He also proposed manned Mars missions using nuclear propulsion and artificial gravity, along with the first use of a camera in the digital domain for spacecraft navigation, guidance and general photography.
The Death of Rocket Science in the 21st Century

by Glen A. Robertson and Darryl W. Webb

Throughout the modern literature on rocket science as it applies to earth-to-orbit spaceflight, there is a strong engineering mindset that lacks a true understanding of the fundamental problem that spacecraft propulsion technologies (including fuel and associate hardware) drives everything that can be done in space, as it constitutes the majority of the weight of modern launch vehicles. Therefore, the key to advancing spaceflight lies as a foundation in rocket science toward the research and development of new propulsion technologies and is the thesis of this article.

Within conventional rocket science, this engineering mindset drives the spacecraft community to blindly design spacecraft within a knowledge base that forbids the introduction of new science teachings into the research of new thrust methods and thus new propulsion systems. Whereby, the design of systems to provide propulsive forces using current propulsive or aerospace engineering understandings of spaceflight depends primarily on the application of Newton’s third law of reciprocal actions – for a force there is always an equal and opposite reaction: or the forces of two bodies on each other are always equal and are directed in opposite directions. That is, current propulsive systems are primarily focused on the brute force application of mass ejection to overcome gravity and inertia without truly understanding either, regardless of the mechanism (thermo, electric, nuclear & etc.). This flaw is a direct result of the mission mentally that drives the research and development for new spacecrafts toward a purely engineering prospective, which results in each new spacecraft being more akin to next year’s model than an evolutionary next forward. This is not to say that conventional rocket science has not given incredible advances in spaceflight capability during nearly a century of endeavors.

A visualization of cycles in human events can be shown in a Kondratieff Interval (proposed by Nikolai Kondratieff in 1924), which shows roughly a 55-year cycle in human events. A Kondratieff Interval showing the steps toward spaceflight was done by William B. Scott in “To the Stars,” published in the March 1, 2004 issue of Aviation Week & Space Technology, using the work of John E. Allen in “Quest for a Novel Force: A Possible Revolution in Aerospace,” published in Progress in Aerospace Sciences, 39, 2003, pp. 1-60. Scott noted that the Kondratieff cycle appears in key space flight milestones, and that another breakthrough is due around the year 2012.

Figure 1 extends the Scott-Allen Kondratieff Interval to 2067. Although informative, it is a bit misleading as rockets capable of manned spaceflight are thermo-chemical rockets.

Figure 1. The extended Scott-Allen Kondratieff Interval
With respect to the Kondratieff Interval, rocket science can be divided into the three intervals as follows.

**Interval of Discovery**

The first interval of rocket science was one of discovery. It began in the early 1900s and ended in the late 1950s. This interval is highlighted by the following:

1912–The engineer Robert Esnault-Pelterie published a lecture on rocket theory and interplanetary travel.
1912–Dr. Robert Goddard (a U.S. professor and scientist) began a serious analysis of rockets, concluding that conventional solid-fuel rockets needed to be improved in three ways.
1923–The physicist Hermann Oberth published *Die Rakete zu den Planetenräumen* ("The Rocket into Planetary Space"), a version of his doctoral thesis, after the University of Munich rejected it.
1930s–In the early 1930’s, rocket clubs sprang up all over Germany.
1943-44–The V-2 rocket was the first ballistic missile and first man-made object to achieve sub-orbital spaceflight. It was the progenitor of all modern rockets including the Saturn V moon rocket.
1949–*Rocket Propulsion Elements* by George P. Sutton, which sums the work by Tsiolkovsky, Goddard and others.
1953–First launch of the American Redstone rocket, which was a direct descendant of the German V-2.
1957–Sputnik 1 (the world’s first Earth-orbiting artificial satellite) was launched into a low altitude elliptical orbit by the Soviet Union.
1959–Luna 2 (the first craft on the Moon) was the second of the Soviet Union’s Luna program spacecraft launched in the direction of the Moon, and is most famous for confirming the earlier detection of the solar wind by Luna 1.
1957-58–The Jupiter-C was a type of sounding rocket used for three sub-orbital spaceflights. The Jupiter-C successfully launched the West’s first satellite, Explorer 1, on January 31, 1958. This event signaled the birth of America’s space program.

**Interval of Engineering**

The second interval of rocket science was one of human spaceflight engineering, which began in the late 1950s and started to end in 1981 at the launch of the Space Shuttle. Thereafter, a more widespread development of spaceflight across the globe began. This interval is highlighted by the following events:

![Figure 2. Intervals toward the 21st Century of Space Flight](image-url)
1958–NASA was established by law and the 50th Redstone rocket was successfully launched.
1961–Yuri Alexeyevich Gagarin became the first human in space and the first to orbit the Earth.
1959-63–Project Mercury was the first human spaceflight program of the United States. The Mercury-Atlas 6 flight on February 20, 1962 was the first Mercury flight to achieve this goal.
1965-66–Project Gemini was the second human spaceflight program of the United States with 10 manned flights occurring in. Its objective was to develop techniques for advanced space travel.
1961-75–The Apollo program was a human spaceflight program undertaken by NASA with the goal of conducting manned moon landing missions with the first of five manned moon landings on July 20, 1969.
1972-Present–The Shuttle program developed a reusable space shuttle system, which was first launched on April 12, 1981.
2003–The Chinese space program launches its first manned space flight, Shenzhou 5 on October 15.
2006–NASA establishes the manned return to the moon, Constellation program; cancelled under the current (2010) administration.
2008–The Chinese space program launches its third manned space flight carrying its first three-person crew and conducts its first spacewalk, becoming the third nation to do so.

**Interval of Commercialism**

The third interval of rocket science is one of commercialism. Commercialism of modern rocketry is a death-knell for rocket science as a pure science. Commercialism even with the best intentions is most about dollars and less about research toward new models and theories that would bring about future rocket systems. Case in point is the automobile industry, which is more about new features (sales) than about developing new propulsive mechanisms (i.e., where are the flying cars?). The prevalent cases for the commercialization of manned space are:

2004–SpaceShipOne makes the first privately-funded human spaceflight, June 21.
2008–NASA awards Space Exploration Technologies, or SpaceX, a (earth-to-orbit manned) Launch Services contract for the Falcon 1 and Falcon 9 launch vehicles.
2010–The US plans moving away from NASA derived earth-to-orbit manned launch systems toward commercial systems as Falcon 9 derived system.

Most of these highlights are presented in a Kondratieff like interval in Figure 2, where the first 40-45 years represents the birth of space rocketry, the next 37-41 years represents the interval of rocket science, and the years thereafter presents the death of rocket science. The intervals in Figure 2 present a story that begins with fantasy, and then lays dormant for years within various rocket societies while engineers figure how to bring fantasy to a reliable field of rocket science. Rocket science got a boost going toward WWII with the development of the V2, later by the cold-war, which lead to the development of NASA in 1958 with a formally established manned space program in place by the early 1960s. At the end of the Apollo program, rocket science was reduced to pure engineering as the US moved toward a single space shuttle system that has dominated US civilian manned space launch since.

US civilian spaceflight through the interval of rocket science (engineering) can be better analyzed by comparing the rocket engine energy density (specifically liquid engine) versus time to other engines, such a comparison is presented in Figure 3. As shown, each line of data represents various engine developments starting with locomotives beginning in the late 1800s through air and space flight into the early 2000s. The 37- 41 years of rocket science in Figure 2 is well represented by the liquid rocket engine development, which from the 1950s to about 1981 was increasing at a rate of ~2.9% per year (see Figure 3). This abruptly stops with the Space Shuttle launch in 1981, bringing with it the gradual death of rocket science toward a more commercial truck-like service versus a rocket science endeavor.

An important indicator in the death of rocket science is the apparent wavering of paradigms in the development of earth-to-orbit vehicles. Beginning with the US reusable

![Figure 3. Energy Density versus Time](image-url)
rocket-plane programs, the leading manned space vehicle designs in the US until the establishment of NASA in 1958, which lead to expendable earth-to-orbit rocket programs used in the moon race of the 1960s. Then in the 1970s, the return to a reusable rocket-plane (i.e., Space Shuttle), and in 2005 a return to an expendable earth-to-orbit rocket program. Such wavering paradigms are a formable indication that engineers are struggling for new directions in propulsion technology.

Performance toward breakthroughs or event changers is the product of extraordinary, rare and gifted individuals, or the lucky happenstance of coincidental circumstances and fortuitous historical forces. In both cases, it is believed that event changers in spaceflight are considered beyond the reach of current rocket science, as such is not within the knowledge base to make happen within a normal time frame as depicted by a Kondratieff Interval. This is evident in the fact that at this writing, there is no expected event changer in spaceflight, manned or unmanned, foreseen for 2012, or in the next 20 years for that matter, that is not of engineering origin. A development looks new, but is just a different model. It is no more a new invention than next year’s automobile.

The establishment of performances leading to breakthroughs or event changers goes beyond “Declaring an Authentic Vision That Calls People beyond Existing Frontiers” or making “Bold Promises to Fulfill the Declaration,” but requires “A New Mindset in Leadership and Management” that rocket science alone does not contain the knowledge base required to lead such breakthrough performances. That is, there is a need to development a new discipline and profession; we’ll call it Space Propulsion Science, which can produce the extraordinary, rare and gifted individuals who can lead the field of rocket science in new directions or frontiers unattainable in current rocket science teachings. Without such professional leadership, performance toward event changers in spaceflight will be slow and come about only through the lucky happenstance of coincidental circumstances or fortuitous forces; i.e., global political pressures.

Space propulsion science involves the development of new theories, the derivation of new mathematical formulations, or the research of new concepts derived from these theories and derivations toward providing scientific knowledge that can be used by engineers to design future launch vehicles using propulsion ideas and concepts that are only now coming into focus (for examples see: “7th Symposium On New Frontiers In The Space Propulsion Sciences” in Space, Propulsion & Energy Sciences International Forum (SPESIF-2010)). The discipline of space propulsion science offers a radical, counter-intuitive view that the performance toward event changers can be learned and intentionally carried out by individuals and teams with the proper knowledge base and organizational commitment. Further, space propulsion science would put in place “levers and dials” (for example see Figure 5) toward breakthrough performance that would make an individual or organization “extraordinary, rare and gifted.” Rather than identifying some innate capacity, this refers instead to creating and fulfilling a powerful vision of space exploration extending beyond our solar system. As it is believed that the discipline of space propulsion science is somewhere between the disciplines of astrophysics and high energy physics; involving the understanding of matter in the cosmos and its physical properties down to energy scales undetectable by normal engineering methods is required. The discipline would require knowledge in Relativistic Field Theory (i.e., General Relativity or space-time), Quantum Field Theory and the like, but focused on the understanding of inertial and gravitational forces toward applicable propulsive forces for spaceflight.

The fact is that in both Relativistic Field Theory and Quantum Field Theory, there can be found examples where objects can be accelerated by changing the external energy density profile; representing a radical change from mass ejection used in modern rocket science. For examples see; Frontiers of Propulsion Science by Marc G. Millis and Eric W. Davis, and “New Frontiers in Space Propulsion Sciences” by Glen A. Robertson, P. A. Murad, and Eric Davis in Energy and Conversion Management.

For rocket science and space propulsion science to form a union toward future spacecraft propulsion system development, a means to unite them is needed. Such a union can be made using the similarity between design and research, as engineering is in effect a form of design.

The Nobel Laureate Herbert Simon affirmed that design is an essential ingredient of the artificial sciences and, consequently, a required process in professional activities, especially in engineering, architecture, education and business. Ranulph Glanville, president of the American Society for Cybernetics and expert in design theory, affirms that “Research is a variety of designs. So do research as design,” and, “Design is key to research. Research has to be designed.” Further, C. Frayling asserts that “doing science is much more like doing design.”

Both design and research are characterized by iterative cycles of generating ideas and confronting them with the world. Both science and design use generative and evaluative thinking, but science stresses the evaluative thinking (by logic, deduction, strict and mostly explicit definitions, verbal notations, etc.), while design focuses on the generative thinking (which is usually associative, analogical, and inductive thinking, using loose definitions, and supported by visual representation as doodling, sketching, diagramming, prototyping, etc.)

An increasing number of authors, especially in the last decade, are stressing the relationships between design and research. Design is, implicit or explicitly, an essential activity in natural science research, and an explicit backbone of the artificial sciences (engineering, architecture, etc.). In turn, design, implicitly or explicitly, includes research activities. In natural sciences, design...
activities (hypothesis construction, experiment design, etc.) are means used in research, with the purpose of generating knowledge to be evaluated (validated and/or verified). In artificial sciences research is one of the means used to generate the knowledge required for design effectiveness. In other words, design is a mean for research, and research is a mean for design. Design and research are related via cybernetic loops in the context of means-ends logic. A visual schematization of the most fundamental relationships between design and research is shown in Figure 4.

Research nurtures disciplinary knowledge and design is usually nurtured by several scientific disciplines, especially in the case of engineering, architectural, etc. designs. Consequently, a multidisciplinary field is one of the most adequate contexts for the organization of design and research. Furthermore, according to Richard Buchanan, one of the four designing areas “is the design of complex systems or environments for living, working, playing and learning, and he associates this area to the System Approach and Systems Engineering (Systemics). An increasing number of authors are also associating design concepts to those of cybernetics, and, since one of the four areas defined by Buchanan is “Design of Symbolic and Visual Communications,” Informatics and cyber-technologies are increasingly being used in the design of Visual Communication (Visual Computing, Human-Machine Interface Design, Web Design, Multimedia Design, Graphic Computing Design, etc.)

Simon’s model relating the fundamentals of design and research is given in terms of engineering and research with the relationship between rocket science and space propulsion science in Figure 5. As shown, the current paradigm follows a direct path from the disciplines of rocket science toward a given mission having a specific application to generate concrete knowledge. As noted by the missing elements, the current paradigm prevents the development of any abstract disciplinary knowledge from being utilized by the rocket science discipline due primarily to the lack of a space propulsion science discipline to provide the linkages for:

1. Synergies – Methods for positive and negative feedback and feed-forward-loops
2. Input from the multi-disciplinary knowledge base of the space propulsion science Community for induction into experimental technologies, and
3. Input from the multi-disciplinary knowledge base of the multi-disciplinary rocket science Community for the generation of new forward (or abstract) disciplinary knowledge

As we enter the 21st century, it has been found that modern rocket science as an engineering discipline is at a standstill toward the next Kondratieff Interval event of 2012, which was predicted to make a paradigm shift in how humans get to space. This standstill came about by a void development between science and engineering as it relates to the advancement of the propulsion sciences. However, as presented this void can be fixed through the development of a new discipline called space propulsion science which involves the development of new theories, the derivation of new mathematical formulations, or the research of new concepts derived from these theories and derivations toward providing scientific knowledge that can be used by engineers to design future spacecrafts using propulsion ideas and concepts that are only now coming into focus.
Figure 5. Space Propulsion Design and Research Fundamental Relationship

The fundamental relationship (Figure 5) between rocket science and space propulsion science is essential for the progression of all future space propulsion systems. As such, our universities need to develop curriculums focused on space propulsion science and our aerospace communities (government and commercial) need to develop a formal structure that embraces and sustains space propulsion science as an essential part of their organizations and considers it an essential growth mechanism.

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Glen A. Robertson is President and Chief Technologist for the Institute for Advanced Studies in the Space, Propulsion & Energy Sciences; a not-for-profit organization. He also spent 23 years as an aerospace engineer for the NASA’s Marshall Space Flight Center.

Although Mr. Robertson is affiliated with the NASA Marshall Spaceflight Center, this paper does not necessarily reflect the views and thinking of NASA or any other US government agency. Although Mr. Webb is affiliated with The Aerospace Corporation, this paper does not necessarily reflect the views and thinking of The Aerospace Corporation or any other US government agency.
The Radio Aurora EXplorer
by Allison Craddock and James Cutler

Weighing in at less than three kilograms (6.6 lbs.) and measuring thirty centimeters (11.8 in.) by ten centimeters (3.9 in.) square, the Radio Aurora EXplorer (RAX) is the first National Science Foundation sponsored satellite mission. It was designed and built by University of Michigan students and faculty, in partnership with SRI International, within seventeen months of the funding award.

The primary mission objective of RAX is to study plasma instabilities that lead to magnetic field-aligned irregularities (FAI) of electron density in the lower polar thermosphere. Occurring at 80 to 400 kilometers above sea level, these irregularities are known to disrupt communication and navigation signals between the ground and orbiting spacecraft. Earth-based scientists have been unable to study these unique plasma formations from the ground, and RAX will serve as the enabling component of this research.

Once the RAX satellite is in orbit, the mission team will utilize a network of existing ground radars to scatter signals off of the FAI. A receiver on RAX will then measure these signals to aid SRI and Michigan scientists in identifying patterns for forecasting FAI formation, or more colloquially, space weather. Secondary mission objectives of RAX include: global UHF emission level characterization, spacecraft performance measurements, magnetometer performance experiments, and educational training of next generation space engineers. These secondary missions will aid students in the understanding of their system performance and determine how improvements can be made on future spacecraft.

RAX was built in response to a growing demand for smaller, more affordable satellites able to perform science missions. It is based on the cube satellite, or “CubeSat” concept, a standardized platform that enables launch vehicles to provide affordable access to space when there is room on their rockets for small spacecraft. The CubeSat trend began at Stanford University and CalPoly San Luis Obispo in the early 2000s. One of the most compelling qualities of a CubeSat is its ability to optimize space and weight. CubeSats may easily replace traditional ballast on rockets, thus allowing students access to space in an unprecedented manner. Over thirty CubeSats have been launched since the concept was conceived, demonstrating the potential to influence a whole-scale reduction on the cost of access to space for smaller space missions. Tremendous effort has been put into ensuring that these CubeSats can deorbit properly, in order to avoid creating space debris.

For the past year, the RAX team, led by Professor James Cutler and assisted by post-doctoral researcher Andrew Klesh and graduate student Matthew Bennett, has been busy constructing the unit almost entirely from scratch. Much of the spacecraft required custom-made components, presenting a variety of challenges to the design process. The final unit was assembled at the end of January, and quickly underwent functional and environmental testing.

To build RAX, the team implemented a continuous improvement model, a process in which team members build the unit, prepare it for flight, and note any changes that should be made in the next generation. The team then builds another unit with the previously noted improvements and design updates, and if time allows, swaps this unit for flight. This method has allowed RAX to be constantly improving, with parts being tested using such alternative methods as high altitude balloons. The real benefit to this model is that each generation of the equipment is better than the last, with the testing of previous generations making key contributions to future development. The scheduled launch date has moved several times, and the team has been able to use this to its advantage by being always ready and still improving at the same time.

RAX undergoes the same rigorous testing that its bigger cousins do, to meet many of the same performance requirements for launch. During testing, RAX was able to successfully upload commands and receive telemetry from a host of sensors.
These sensors yielded data including temperature and voltage, GPS position and velocity, spacecraft attitude (for orientation determination), and the general status of all of the RAX subsystems.

The radar receiver was tested with the use of a radar signal simulator, and data processing and compression of the received data was demonstrated at a reduction of over 4000 to 1. All of this data was then transmitted to the ground station. The GPS receiver was tested at Orbital Sciences Corporation in an orbit simulator, thus confirming that the receiver works at orbital velocities and altitudes. The ground station software was also tested over radio links, proving that the team will be able to listen and interact with RAX remotely.

Recently, the satellite completed integration and vibration testing at Cal Poly San Luis Obispo. The unit was inserted into a deployment mechanism that shook it to the same levels that will be experienced on the rocket on its way into orbit. RAX passed with flying colors.

Physical testing was continued in Michigan’s Student Space System Fabrication Labs (S3FL) through the use of the thermal vacuum facility funded by the NASA Jet Propulsion Laboratory. There, the team ran the system to ensure that RAX could withstand the extreme environment of space. Thermal testing took place in a testing chamber donated to the university by Lockheed Martin. After all of this rigorous testing, it was determined that RAX was able to successfully deploy its antenna and perform mission operations. Final testing included measuring the unit’s mass properties, and determining the moments of inertia by placing RAX on a custom designed spinning platform.

Over the course of the seventeen-month development, the team also built additional testing facilities to evaluate sensors and prototypes. An in-house Helmholtz Cage was constructed to create and simulate the changes in magnetic fields experienced by the satellite throughout its orbit over time. The cage was designed to characterize the magnetometers and run hardware-in-the-loop testing with RAX. This essentially puts the CubeSat into a virtual orbit, and allows the team to generate appropriate magnetic fields to test RAX’s ability to determine how it is oriented. The Helmholtz Cage is also used to evaluate magnetic cleanliness and final integration testing.

A multi-station clean room was also constructed in the basement of the François-Xavier Bagnoud (FXB) Building, home of the Aerospace Engineering Department, allowing a sterile environment for the fabrication of components bound for space. In the clean room, components were soldered onto boards, cleaned with alcohol and coated with a conformal epoxy to prevent elements from shorting out and to distribute heat. These final boards were then baked out to eliminate moisture and complete the curing process. Now that RAX has been constructed, these facilities are being used to continue the characterization of the small spacecraft and its sensors.

At the time of this writing, the team is gearing up to ensure that RAX is ready for its delivery for integration in the spring of 2010, and its subsequent launch off of a Space Test Program (STP) Minotaur IV rocket expected later in 2010 from Kodiak Launch Complex in Alaska. Once in orbit, RAX will study properties of the upper atmosphere and ionosphere using a custom-designed radar receiver. All data collected during this mission, including telemetry and mission science results, will be published and easily accessible to everyone through the RAX mission website. Follow the mission’s progress on its website: http://rax.engin.umich.edu/.
NOTES ON A NEW BOOK

Space Exploration and Astronaut Safety

Reviewed by Mark Williamson


Safety is not a word historically associated with space exploration. Most people would apply the terms risk, bravery, or “The Right Stuff” to manned space exploits. If they thought about the fates of the Space Shuttles Challenger and Columbia, they might choose words such as accident, disaster, or incompetence. But safety is a concept that’s hard to link with the “conquest of the Moon,” the “Cold War space race,” and the opening of “the final frontier.” A bit like the concept of non-competitive motor racing.

In the real world of space systems engineering, however, risk and safety are two sides of the same coin. Yes, space exploration is inherently risky, but then so is crossing the street. The role of the engineer is to manage the risk and reduce it to acceptable levels, which will, by default, improve safety. In fact, space safety has become an “approved buzzphrase” among space professionals in the past few years, to the extent that conferences and colloquia have been organised to discuss it.

This book is based to an extent on a study – called Space Safety 2005 – which was conducted at George Washington University, where the principal author is Director of Space and Advanced Communications Research. Part history, part technology, and part policy analysis, it reviews NASA’s space exploration programme and astronaut safety programme, considers the current status of the Shuttle and International Space Station, and looks at the options and opportunities offered by the forthcoming Constellation programme. The volume is illustrated with black and white photos and diagrams and concludes with a useful 18-page index. It also has about 80 pages of appendices, which include an acronym list and substantial technical reviews of Shuttle and ISS “Vulnerabilities.” For the Shuttle, this highlights the self-evident risks of launch and landing, but also covers aging, corrosion, wiring problems, and issues with retrofitting systems and components.

Although this is, without doubt, a technical book, it is well written and organized, partly due to the experience of editor Peter Marshall, who the author credits with making it “a crisper product.” Pelton, himself, is no amateur when it comes to book writing, with more than two dozen to his name, and it is his experience that comes through in the writing.

One of the key chapters comes towards the end of the book. Entitled “Lessons Learned in Space Safety and Ongoing Issues,” it looks towards NASA’s post-Shuttle future, in which Project Constellation takes astronauts back to the Moon, and hopefully beyond. According to Pelton, “Safety must be approached as a system rather than a collection of parts, and it must be engineered and designed in rather than trying to use reliability testing to ‘weed out’ weak links.” “Ultimately safety must be a state of mind and an inbred culture,” he adds.

Apparently unhappy with the way that Constellation was “defined in only a matter of a few weeks under the constraints of a presidential deadline rather than [an] open forum of competitive ideas,” the author calls for a “broader and more open process” that would “include at least a reappraisal of Project Constellation.” Unfortunately, history has shown that American manned space programmes tend to be decree- and deadline-led, only include elements of competition at the hardware contracting level, and suffer an overlay of NASA field centre infighting and pork-barrel politics. Some two years after Pelton made his recommendations, contracts for Constellation hardware had been let and NASA management made it clear that it was too late for fundamental redesigns. How safe the resulting hardware proves to be, of course, remains to be seen.

Perhaps equally as important as safety design for the future of US manned space exploration is the education of its fickle and emotionally-led media, and thus public, regarding the true nature of risk and reward. Former US deputy secretary of defense, Cyrus Vance, who is quoted in the book, had it absolutely right: “The nation must expect such a loss of life in the space program…We would be untruthful if we were to present anything different to our citizens.” This was true in 1965, when America was half way through its development of Apollo, and it is true today.

Mark Williamson is an independent space technology consultant and author.
CALL FOR PAPERS

21st AAS/AIAA Space Flight Mechanics Meeting
Loews New Orleans Hotel
New Orleans, Louisiana
February 13 - 17, 2011

The 21st Space Flight Mechanics Meeting will be held February 13 - 17, 2011, at the Loews New Orleans Hotel in New Orleans, Louisiana. The conference is organized by the American Astronautical Society (AAS) Space Flight Mechanics Committee and co-sponsored by the American Institute of Aeronautics and Astronautics (AIAA) Astrodynamics Technical Committee. Papers are solicited on topics related to space flight mechanics and astrodynamics, including but not limited to:

- Asteroid and non-Earth orbiting missions
- Atmospheric re-entry guidance and control
- Attitude dynamics, determination and control
- Attitude-sensor and payload-sensor calibration
- Dynamical systems theory applied to space flight problems
- Dynamics and control of large space structures and tethers
- Earth orbital and planetary mission studies
- Flight dynamics operations and spacecraft autonomy
- Orbit determination and space-surveillance tracking
- Orbital debris and space environment
- Orbital dynamics, perturbations, and stability
- Rendezvous, relative motion, proximity missions, and formation flying
- Reusable launch vehicle design, dynamics, guidance, and control
- Satellite constellations
- Spacecraft guidance, navigation and control (GNC)
- Trajectory / mission / maneuver design and optimization

In addition to the above general topics, papers are also solicited for the following special topics:

- NASA decadal survey studies
- Innovative guidance and control test solutions

Manuscripts will be accepted based on the quality of the extended abstract, the originality of the work and/or ideas, and the anticipated interest in the proposed subject. Submissions that are based on experimental results or current data, or report on ongoing missions, are especially encouraged. Complete manuscripts are required before the conference. The working language for the conference is English.

SPECIAL SESSIONS

Proposals are being considered for suitable special sessions, such as topical panel discussions, invited sessions, workshops, mini-symposia, and technology demonstrations. A proposal for a panel discussion should include the session title, a brief description of the discussion topic(s), and a list of the speakers and their qualifications. For an invited session, workshop, mini-symposium, or demonstration, a proposal should include the session title, a brief description, and a list of proposed activities and/or invited speakers and paper titles. Prospective special-session organizers should submit their proposals to the Technical Chairs.
BREAKWELL STUDENT TRAVEL AWARD
The AAS Space Flight Mechanics Committee announces the John V. Breakwell Student Travel Award. This award provides travel expenses for up to three (3) U.S. and Canadian students presenting papers at this conference. Students wishing to apply for this award are strongly advised to submit their completed paper by the abstract submittal deadline. The maximum coverage per student is limited to $1000. Details and applications may be obtained via http://www.space-flight.org.

INFORMATION FOR AUTHORS
Because the submission deadline of October 11, 2010 has been fully extended for the convenience of contributors, there are no plans to defer this deadline due to the constraints of the conference planning schedule. Notification of acceptance will be sent via email by November 20, 2010. Detailed author instructions will be sent by email following acceptance. By submitting an abstract, the author affirms that the manuscript’s majority content has not been previously presented or published elsewhere. Authors may access the web-based abstract submittal system using the link available via the official website http://www.space-flight.org. During the online submission process, authors are expected to provide:
1. a paper title, as well as the name, affiliation, postal address, telephone number, and email address of the corresponding author and each co-author;
2. an extended abstract in the Portable Document File (PDF) format of at least 500 words that includes the title and authors, and provides a clear and concise statement of the problem to be addressed, the proposed method of solution, the results expected or obtained, and an explanation of its significance to astrodynamics and/or space-flight mechanics, with pertinent references and supporting tables and figures as necessary; and
3. a condensed abstract (100 words) to be included in the conference program, which is directly typed into the text box provided on the web page and avoids the use of special symbols or characters, such as Greek letters.
Foreign contributors requiring an official letter of acceptance for a visa application should contact the Technical Chairmen by email at their earliest opportunity.

Technology Transfer Notice  Technology transfer guidelines substantially extend the time required to review abstracts and manuscripts by private enterprises and government agencies. To preclude late submissions and withdrawals, it is the responsibility of the author(s) to determine the extent of necessary approvals prior to submitting an abstract.

No-Paper/No-Podium Policy – A complete manuscript must be electronically uploaded to the web site prior to the conference in PDF format, be no more than twenty pages in length, and conform to the AAS manuscript format. If a complete manuscript is not received on time, then its presentation at the conference shall be forfeited; and if a presentation is not made by an author at the conference, then the manuscript shall be omitted from published proceedings.

Questions concerning the submission of papers should be addressed to the technical chairs.
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All other questions should be directed to the General Chairs.
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The AAS hosted the 12th International Space Conference of Pacific-basin Societies (ISCOPS) July 27-31 in Montréal, Quebec, Canada. The responsibility for hosting this conference, held every two years, is shared by the AAS, Japanese Rocket Society (JRS), and the Chinese Society of Astronautics (CSA). This year attendees came from China, Japan, India, Indonesia, Canada, and the United States. Sessions covered national space programs, astrodynamics, guidance and control, satellite communications, materials and structures, remote sensing, space transportation, propulsion, human space flight, microgravity, planetary exploration, and other related topics.

Over 60 technical papers were presented, and student awards were given for the best papers at the Masters and Ph.D. levels. The Spark M. Matsunaga Award was presented to Professor Arun Misra from McGill University, and a technical tour to the Canadian Space Agency concluded the conference.

The JRS will host the 13th ISCOPS in Japan in 2012.
AAS National Conference

International Space Station: The Next Decade - Utilization and Research

November 16-17, 2010 ■ Radisson Resort at the Port, Cape Canaveral, Florida

Tuesday, November 16

Keynote
Charles F. Bolden, Jr., NASA Administrator (invited)

Panel: Importance of ISS in the Next Decade: Views of the Partnership
Moderator: James Zimmerman, President
International Space Services

Luncheon
Guest Speakers:
Frank DiBello, President and CEO, Space Florida - remarks and introduction
Senator Bill Nelson (D-FL), Chairman, Senate Science and Space Subcommittee (invited)

Positioning ISS for the Utilization Era
Mark Uhran, Assistant Associate Administrator for ISS, NASA Headquarters

Panel: The National Laboratory – Present and Future
Moderator: Marybeth Edeen, Manager, ISS National Lab, NASA JSC

Panel: ISS: Enabling Utilization, Preparing for Exploration and Testing Technology
Moderator: Rick Howard, Deputy Chief Technologist, NASA Headquarters

AAS Honors and Awards Reception
Wednesday, November 17

KSC Update
Robert Cabana, Director, NASA KSC and Symposium Honorary Chair

Panel: Research and Development on the ISS – Scope and Opportunities
Moderator: Rod Jones, Manager, ISS Payloads Office, NASA JSC

Panel: Research and Development on the ISS – Results From the Principal Investigators
Moderator: Julie Robinson, ISS Program Scientist, NASA JSC

Luncheon: A Visual Tour of the ISS
Guest Speaker: Astronaut or former Astronaut

ISS – Inspiring and Educating
James Stofan, Associate Administrator for Education (Acting)
NASA Headquarters

Panel: Supporting ISS Operations in the Post-Shuttle Era
Moderator: Lynn Cline, Deputy Associate Administrator, Space Operations Mission Directorate, NASA Headquarters

Direct from the ISS: Closing Comments from ISS Crew Closing Reception

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September 20-22, 2010
International Symposium on Asteroid Mitigation
Texas A&M University
College Station, Texas
aeweb.tamu.edu/isam

September 27 - October 1, 2010
International Astronautical Congress (IAC)
Prague Congress Centre
Prague, Czech Republic

October 10-24, 2010
USA Science & Engineering Festival
Washington, DC
www.usasciencefestival.org

October 25-27, 2010
*Von Braun Memorial Symposium
Chan Auditorium, Business Administration Building
The University of Alabama in Huntsville
Huntsville, Alabama
www.astronautical.org

November 16-17, 2010
AAS National Conference
"ISS: The Next Decade"
Radisson Resort at the Port
Cape Canaveral, Florida
www.astronautical.org

February 4-9, 2011
AAS Guidance and Control Conference
Beaver Run Resort and Conference Center
Breckenridge, Colorado
www.aas-rocky-mountain-section.org
Abstract Deadline: September 1, 2010

February 13-17, 2011
*AAS/AIAA Space Flight Mechanics Winter Meeting
Loews New Orleans Hotel
New Orleans, Louisiana
www.space-flight.org
Abstract Deadline: October 11, 2010

March 15-17, 2011
Space, Propulsion & Energy Sciences International Forum
University of Maryland
College Park, Maryland
www.ias-spes.org/SPESIF.html

March 30-31, 2011
49th Robert H. Goddard Memorial Symposium
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Northrop Grumman
Orbital Sciences Corporation
Paragon Space Development Corporation
The Pennsylvania State University
Phillips & Company
Raytheon
RWI International Consulting Services
SAIC
The Tauri Group
Technica, Inc.
Texas A&M University
United Launch Alliance
Univelt, Inc.
Universal Space Network
Universities Space Research Association
University of Alabama in Huntsville
University of Florida
University of Texas at Austin
Utah State University / Space Dynamics Lab
Women in Aerospace