SPACE TIMES

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ON THE COVER

FRONT: NASA's Ares I-X test rocket soars into blue skies above Launch Pad 39B at NASA's Kennedy Space Center in Florida on Oct. 28, 2009. (*Source: NASA/Sandra Joseph and Kevin O'Connel*)

BACK: A never-before-seen view of the turbulent heart of our Milky Way galaxy as seen by NASA's Great Observatories: Hubble, Spitzer, and Chandra. This view combines near-infrared, infrared, and x-ray wavelengths to provide one of the most detailed multi-wavelength pictures of our galaxy's core. (*Source: NASA, ESA, SSC, CXC, and STScI*)
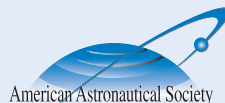
PRESIDENT'S MESSAGE

On October 20 and 21, the AAS, in partnership with the Huntsville chapter of the National Space Club and the NASA Marshall Space Flight Center, hosted the second annual Wernher Von Braun Memorial Symposium. The symposium organizing committee came through with a terrific program capped off by some very warm remarks by NASA Administrator Charles Bolden at the concluding day's luncheon. While we had a very good turnout, in reality only a small part of the AAS membership was in attendance. Consequently, I am providing my opening remarks as this issue's President's Message. I hope it will be of interest.

As we face the challenges of the 21st century, our nation's economy has hit a major rough spot, and it is not at all clear how we will get out of it. Recent remarks by the White House's economic advisor forecast a low rate of new job creation for the foreseeable future, and job creation and income growth have been sluggish for most of the past decade. Many in Washington see green jobs, those tied to reusable and low greenhouse gas emitting technology and infrastructure, as a major opportunity for future economic growth and employment. While these new green jobs will likely be important, in many green technology areas the industry leaders are already established overseas, and recapturing leadership in these markets will be very difficult.

While US ingenuity may overcome these challenges, relying only on green jobs to rekindle our nation's economy is risky. It is more prudent to also invest in other areas where US leadership will produce vibrant economic growth.

Much can be learned from the economic results of our past efforts at human space exploration, most notably, the Apollo program. These lessons show us that we need space exploration now more than ever. In fact, Huntsville itself is an excellent example of how a robust space exploration program benefits our nation.

Apollo did more than just race the Soviet Union to the moon. It changed our nation and our world in ways that are rarely recognized today:

· Apollo included purposefully directed investment in our nation's economic development. Much of the southeastern United States, from coastal central Florida to Louisiana and beyond, was economically behind the rest of the nation in the 1950's, and had been since the end of the Civil War. Apollo investments in NASA facilities throughout much of the South – Florida, Louisiana, Mississippi, Texas, and Alabama – brought good paying jobs, rewarding work, and an influx of industry and skilled professionals that enriched these areas long after the program ended. In fact, many of these same areas have, in recent years, been engines of growth for their states and for our nation. When we spend money to return humans to the moon, we will also be investing in the future development of these and other areas around our nation. Over the long run, this will directly benefit these areas and grow the economy of our nation.

· Apollo and other programs implemented in the wake of Sputnik led to a boon in science, technology, engineering, and mathematics education. This had benefits for staffing the space program but, much more broadly than that, it helped to provide a generation of technical talent that benefited our nation and the world in innumerable ways. The late 20th century's technological explosion in computers, telecommunications, aerospace, and biotechnology, to name just a few, was made possible through the expansion of US technical training capability as well as the motivated students who took advantage of these opportunities. NASA and the Apollo program in the 1960s helped create the demand to which our colleges and universities responded. Once Apollo ended, these facilities, professors, and the like did not fade away but adapted to the needs of the new market.

· As we look to a 21st Century with nations such as China and India graduating many times more scientists and engineers than the US in the midst of a sluggish time for economic growth, space exploration can once again provide a demand pull to create the capability to meet the needs of tomorrow. Apollo was also synergistic with our nation's military space program, much of which was and is still not public. Consequently, many of the science and engineering graduates from the nation's colleges and universities were initially attracted to technical disciplines by the civilian space program, yet their careers were ultimately in the service of our nation's defense. As we seek to retain the asymmetric advantage the US military has gained from its space systems and capabilities, a new exploration program would help assure a stream of new technically trained people for our military space programs.

Finally, it should be noted that the space program is more than a source of knowledge, technology, and jobs. It is also a major source of national pride, and one which has long enjoyed bipartisan support. For decades after the first moon landing, the phrase "If they can land a man on the moon why can't they…" was an everyday expression. Apollo became a metaphor for our nation working together to overcome impossible odds. America's collective psyche badly needs a boost of inspiration. Reaffirming our commitment to a robust space exploration program will help to focus us as a people on the future and restore America's historically well placed optimism that its best days lie ahead.

Frank A. Slazer
digaslaze@mac.com

Radiation Belt Storm Probes

by Jennifer Huergo

Probing the Radiation Belts

Beginning in the spring of 2012, two spacecraft will help to solve mysteries that have swirled above our heads for more than fifty years. NASA's Radiation Belt Storm Probes (RBSP) will explore Earth's radiation belts during a two-year prime science mission, with the goal of providing understanding — ideally to the point of predictability — how populations of relativistic electrons and penetrating ions in space form or change in response to variable inputs of energy from the sun.

The two identical probes will follow similar orbits to identify and quantify the processes that cause acceleration, redistribution, and loss of energetic particles within Earth's space environment including the inner magnetosphere, which extends more than 20,000 miles above Earth's surface.
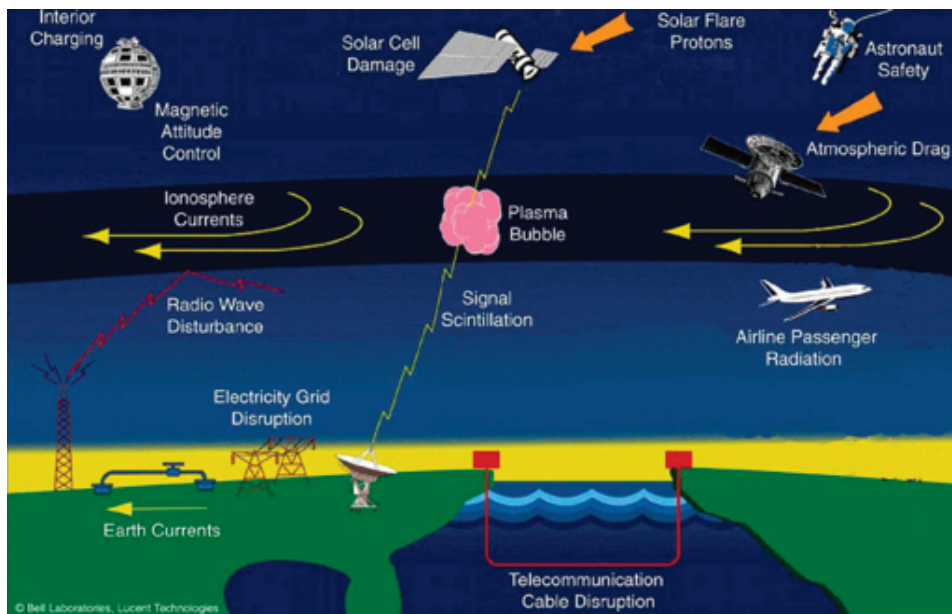
Space weather affects technological systems in space and on the Earth's surface *(artist rendering)*
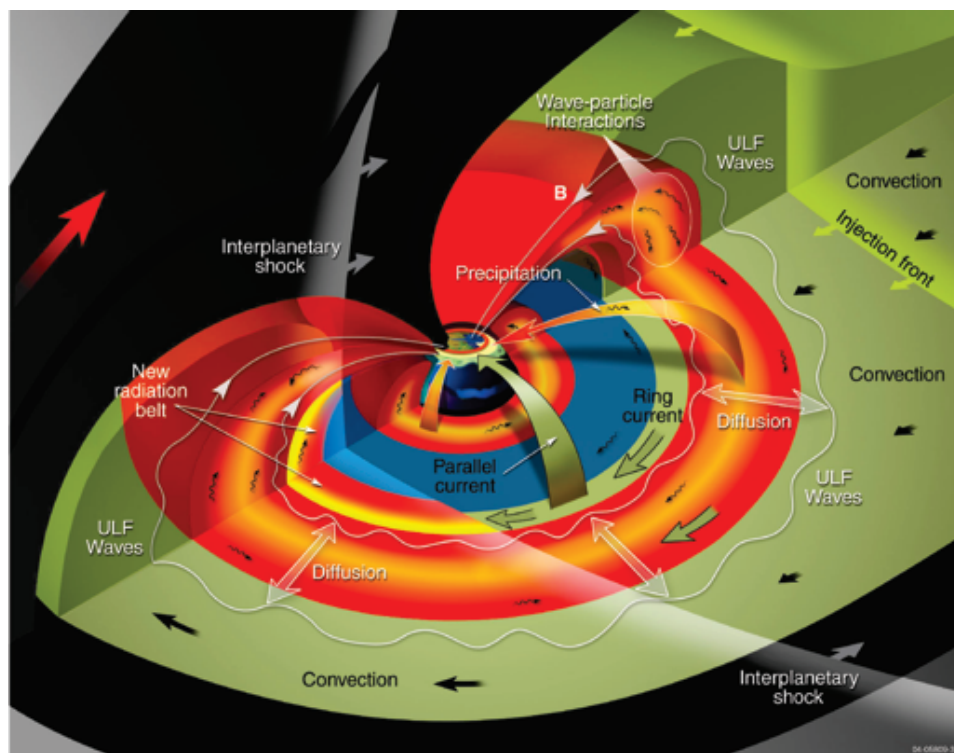
This graphic shows the chain of processes coupling the inner magnetosphere's energetic particle environment to solar wind disturbances *(artist rendering)*

"Although the radiation belts were discovered in 1958, their dynamics are still not well understood," says Nicky Fox, deputy project scientist for the RBSP mission, part of NASA's Living With a Star program, at the Johns Hopkins University Applied Physics Laboratory (APL). "This knowledge is relevant to astronaut safety and spacecraft safety and charging, as well as to systems on the ground. The same processes that enhance the radiation belts drive the substorms that cause aurora, and can cause power grid issues, pipeline failures and GPS receiver errors." The RBSP mission achieves scientific understanding of fundamental physical processes that have very practical consequences, says Fox.

RBSP will try to answer three overarching science questions: Which physical processes produce radiation belt enhancement events, in which the energy of particles and the size of the belts increase? What are the dominant mechanisms for relativistic electron loss? How do ring current and other geomagnetic

processes affect radiation belt behavior? The "ring current" is a gigantic electrical current, carried by energetic charged particles, that encircles Earth at distances greater than 6,000 miles above the planet's surface.

Why Study the Radiation Belts?

Changes in the radiation belts can have a direct impact on human exploration of space, satellite operations, and power and communications down here on Earth. "We want to measure the radiation in the belts and understand the mechanisms behind changes in order to better plan future missions and manned spaceflight, and to better understand the effects on Earth," explains Rick Fitzgerald, RBSP project manager at APL.

The increased density and energy of particles trapped in the radiation belts during geomagnetic storms increases astronaut exposure to particle radiation. These storms can also alter the shape of the magnetosphere, sometimes allowing more high-energy particles into the upper levels of the atmosphere and exposing high-flying airplanes to greater amounts of radiation.

RBSP's data will lead to more accurate models of the radiation belts, which can be used to improve system design. "The more we understand about the radiation belts and about how the sun affects them, the better we can design our satellites and the more reliable we can make our communication systems," says Andy Santo, RBSP deputy project manager at APL.

Modern society's communication and navigation systems rely on hundreds of satellites, most of which operate partly or entirely within the radiation belts. There, particle radiation can overwhelm sensors, damage solar cells and degrade wiring and other equipment. Electric charges can build up inside spacecraft and destroy systems when they discharge.

"It is critical that we understand the environment in which these spacecraft fly," says Fox. "There are regions where the radiation environment is over-estimated and others where it is under-estimated. You assume the worst and overdesign, but the result is more mass than you really needed, and you could have saved money by producing a simpler spacecraft. Alternatively, in other regions you don't predict the hazards enough, and you get a big storm that kills the spacecraft."

Geomagnetic storms sometimes alter the shape and extent of the upper atmosphere, increasing the drag on spacecraft and forcing operators to make corrections to their orbits. The storms can also disrupt radio frequency signals as they travel between satellites and ground stations — including Global Positioning Systems, satellite televisions and car radios.
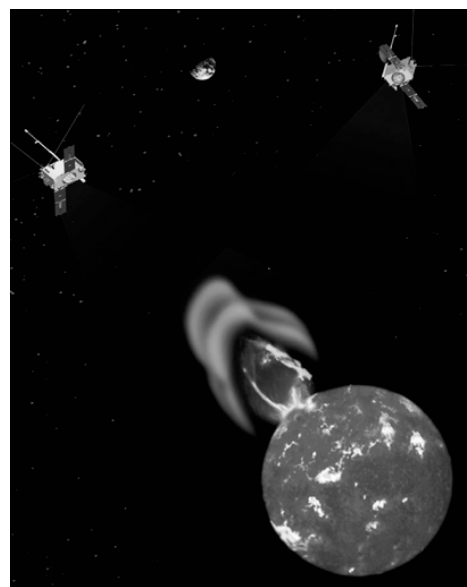
Artist's concept of the twin STEREO spacecraft studying the sun *(artist rendering)*

Large changes in the magnetic field near Earth's surface that are associated with geomagnetic storms can induce currents that flow through railroad systems, power transmission lines and pipelines. These currents can cause minor disruptions in service or major problems such as blackouts, including the March 13, 1989, power grid failure in Quebec, Ontario, that left six million people in the dark.

RBSP will help identify the conditions that can disrupt satellite operations or pose a danger to systems on the ground, and will help develop better predictive models that could give technology operators advance warning of when their systems might be in danger from space weather phenomena.

Instruments

The Applied Physics Laboratory will implement the mission for NASA, building and operating the twin probes. Five teams are providing the instruments that will measure the particles, ionized gases (called plasmas), magnetic and electric fields, and plasma waves that fill Earth's space environment, or geospace. Other spacecraft normally try to avoid this environment, but the probes will need to do more than just survive the harsh conditions, they'll need to operate at full capacity and collect the
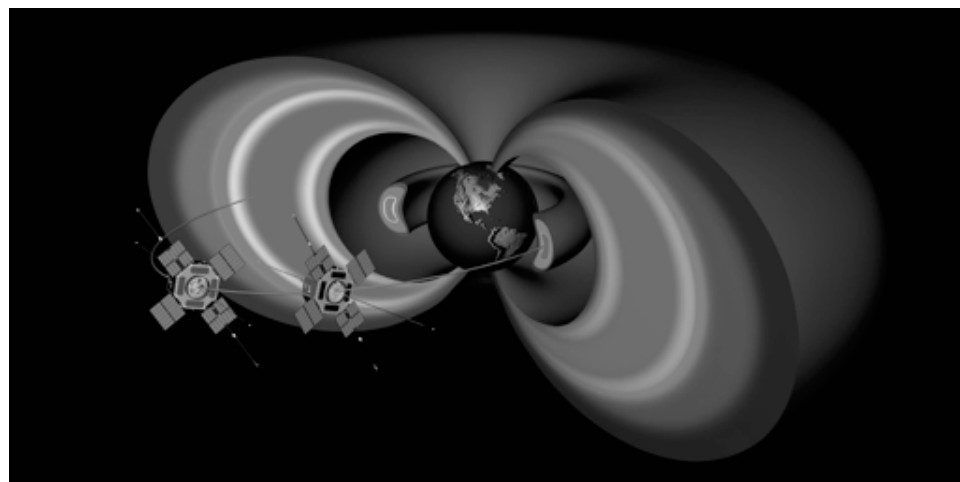
Radiation belt *(artist rendering)*
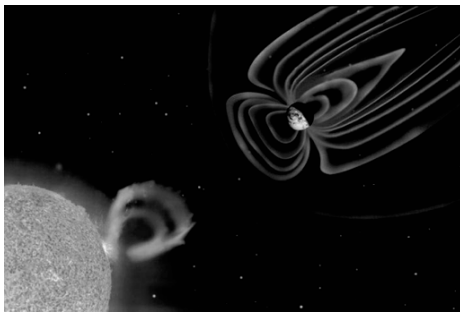
The source of space weather, our dynamic sun, shown with a coronal mass ejection that will interact with the terrestrial magnetosphere producing geospace storms *(artist rendering)*

mission's data. "We've put together the perfect complement of instruments to answer the mission's top-level questions," says Fox.

Lou Lanzerotti, of the New Jersey Institute of Technology, and his team of international collaborators are developing the Radiation Belt Storm Probes Ion Composition Experiment (RBSPICE) to determine how space weather creates the "storm-time ring current" around Earth and to determine how that ring current supplies and supports the creation of radiation populations.

Lanzerotti began investigating Earth's radiation belts as a post-doc at Bell Labs in 1965. "This is like going back to the future for me," he says. "AT&T launched the first communications satellites, Telstar I and Telstar II, and began measuring the trapped radiation from those spacecraft. The RBSP mission provides a unique opportunity to concentrate on Earth's ring current in combination with very good measurements of the radiation belts. RBSPICE will have outstanding energy coverage of the ring current to allow us to understand the basic plasma physics of the trapped radiation."

"I'm very happy to have this opportunity, after a long career in space physics, to be closely involved with a very important mission that will answer many of the questions that I've worked on through the years," says Lanzerotti.

A team led by Harlan Spence of Boston University, is developing the Energetic

Particle, Composition, and Thermal Plasma Suite (ECT). It will directly measure near-Earth space radiation particles to understand the physical processes that control the acceleration, global distribution and variability of radiation belt electrons and ions.

The Electric and Magnetic Field Instrument Suite and Integrated Science (EMFISIS) is being provided by the University of Iowa, Iowa City, under the direction of Craig Kletzing. EMFISIS will focus on the important role played by magnetic fields and plasma waves in the processes of radiation belt particle acceleration and loss.

John Wygant at the University of Minnesota, Minneapolis, is leading development of the Electric Field and Waves Suite (EFW). This instrument investigation will provide understanding of the electric fields associated with particle energization, scattering and transport, and the role of the electric fields associated with large scale plasma flows in modifying the structure of the inner magnetosphere.

The National Reconnaissance Office will contribute the Relativistic Proton Spectrometer (RPS) to measure inner Van Allen belt protons with energies from fifty million-electron volts to two billion-electron volts. Presently, the intensity of trapped protons with energies above about 150 MeV is not well known and is thought to be underestimated in existing specification models. Such protons are known to pose a number of hazards to astronauts and spacecraft, and the project's goal is to develop new standard radiation models for spacecraft design.

The two spacecraft will carry identical instruments so that space environment changes can be tracked in both space and time. "With two spacecraft, we will be able to study small and large-scale features of the events that we're interested in," says Fox. "The spacing between the two
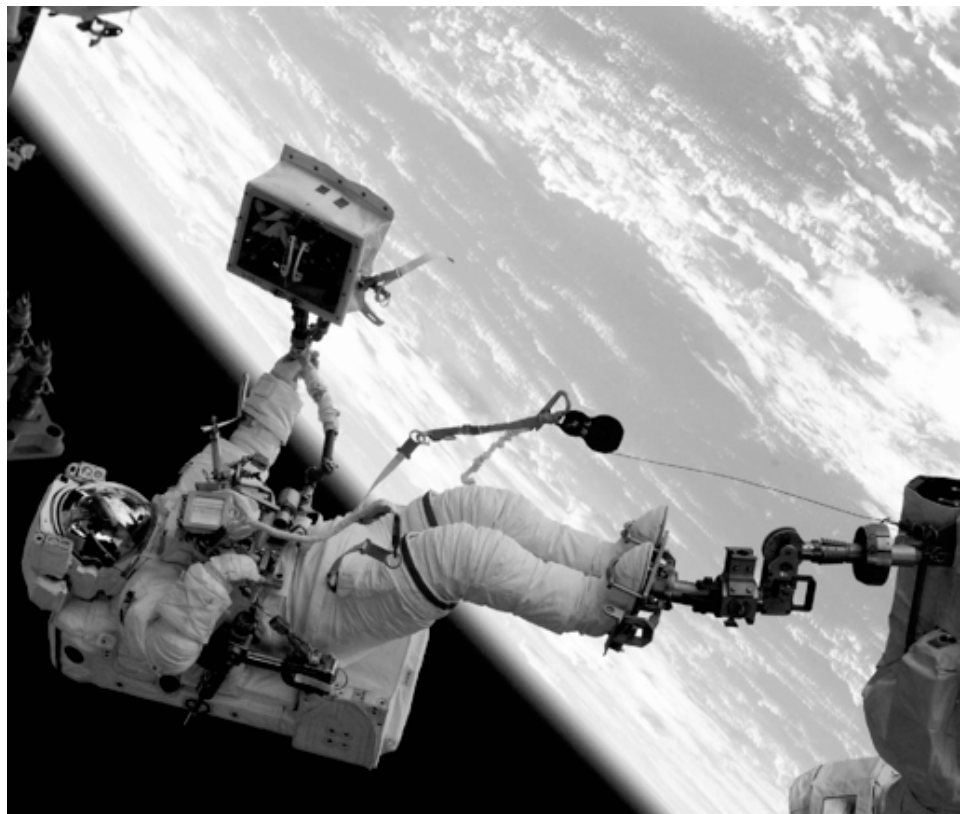
In Earth orbit and in interplanetary space, humans are directly exposed to space weather and its potentially dangerous impact *(artist rendering)*
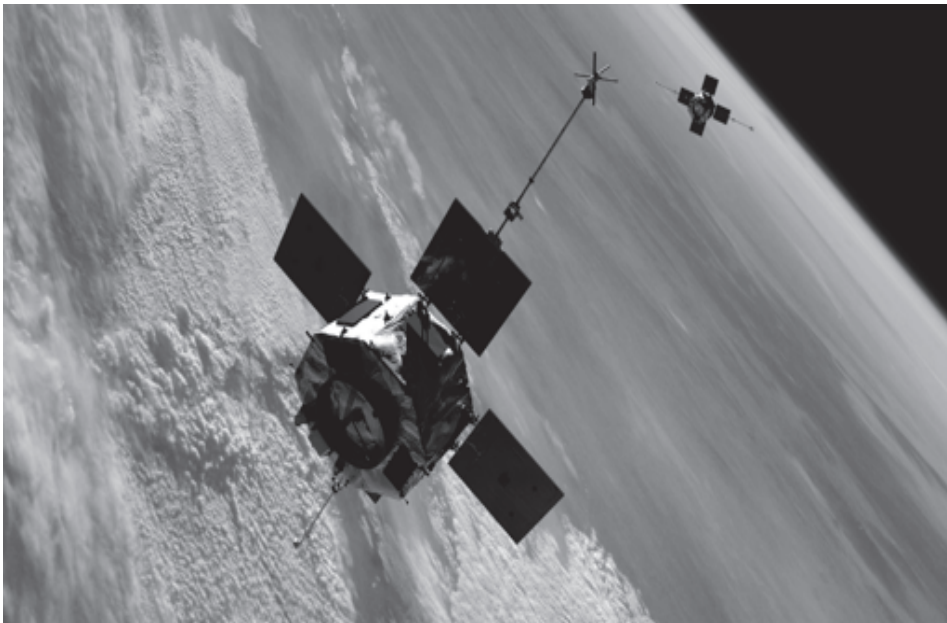
Array deployment *(artist rendering)*

Separation *(artist rendering)*

Stacer boom deploy *(artist rendering)*

SP boom flyby *(artist rendering)*

spacecraft varies continually over the mission so they will lap one another, allowing us to go after different kinds of science. When they're close together, you can do gradients and look for detailed features in the environment. When they're farther apart you have a source region and target region so you can actually deconvolve time and space — you can tell whether a feature just happened in time and disappeared, or whether it's actually a big feature that's covering a larger area."

The highly elliptical orbits of the probes will take them through both the inner and outer radiation belts, from a minimum altitude of approximately 373 miles (600 kilometers) to a maximum altitude of approximately 23,000 miles (37,000 kilometers). "We expect this unique view of the region will provide a spectacular range of data," says Fox.

In December 2009, the RBSP mission will undergo a three-day Critical Design Review to demonstrate that the program's design is ready to proceed to full-scale fabrication, assembly, integration and test. The review will also evaluate whether the technical effort is on track to complete the flight and ground system development and mission operations to meet overall performance requirements within the identified cost and schedule constraints.

"There's still much work to be done as we build the instruments and test our systems in preparation for the 2012 launch, but we are very excited about the mission's progress so far," says Fitzgerald. "Through this mission we hope to gain an understanding of the fundamental radiation processes that occur not only here at Earth, but throughout the universe. That understanding will help us build better spacecraft and better ways to protect our people and technologies, and help us move toward future missions." ∎

Jennifer Huergo **works with the Office of Communications and Public Affairs at Johns Hopkins University's Applied Physics Laboratory.**

Can the Quantum Vacuum be used as a propellant source?

by Harold White, Ph.D.

Imagine if it were possible to utilize the very vacuum of space as a source of propellant. If a spacecraft needed only to provide power, and not carry propellant, what would be the possibilities? A spacecraft equipped with such a propulsion system would have a Specific Impulse (ISP) that is many orders of magnitude higher than current propulsion technology. The limiting design parameter would then be the power density of the local power source. Mission planners could design reference missions to include multiple orbits and inclinations – the latter typically requiring the higher delta-v. A mission could incorporate multiple destinations. Perhaps most importantly for space exploration, transit times could be drastically reduced.

In order to enable bold exploration missions to Mars, the outer solar system, and beyond, advanced propulsion research must be undertaken with the goal of developing point solutions that are orders of magnitude more effective than the current arsenal of propulsion technologies. Propulsion and Power are the keys to exploration, utilization of the Solar System and beyond.

So, again, if it were possible to utilize the vacuum of space as a source of propellant, what would be the possibilities?

The physics community knows from experiments performed over the last ten years that the vacuum is anything but empty. Rather, it is a sea of virtual fields and particles (electron and positron pairs) that pop into and out of existence as they spontaneously create and annihilate. This is otherwise known as the quantum vacuum. Indeed, this phenomenon has been predicted for more than half a century. The substantive question is how can a spacecraft push off of the vacuum of space?

Figure 1. *Gedanken Experiment: Quantum Vacuum Fluctuations and Big-G. The sphere represents the light horizon of the universe with a radius of 13.7 billion light years. The nomenclature "COBE" Sphere is used since the radiation we see today as detected by the Cosmic Background Explorer represents the radiation that was emitted just after the universe transitioned from opaque hot gas to transparent allowing radiation to propagate. The equation on the right is the integral of the pressure over this spherical surface area shown.*

we obtain the Plank Force.

$$\rho_{vac}c^2 \, 4\pi c^2 T_0^2 = \frac{c^4}{G}$$

Vacuum Energy Density — Inner-surface area of COBE sphere — Square of Light radius of COBE sphere

"COBE Sphere"
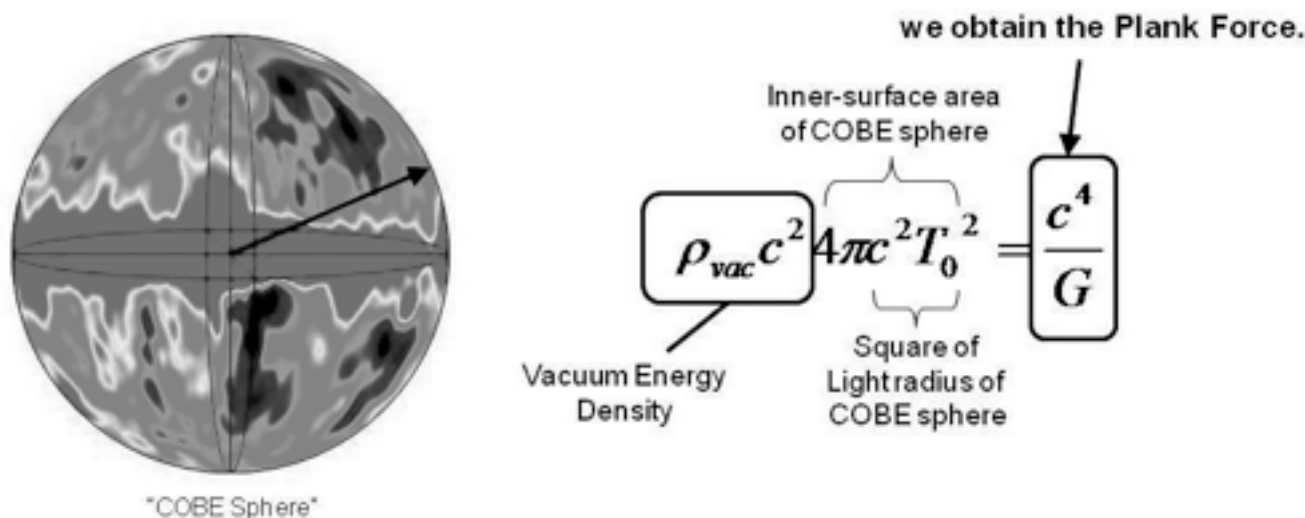
Some theoretical groundwork is in order to help illustrate how this can be done. Consider the following Gedanken experiment (a "thought" experiment). Imagine being an inertial observer in deep space. What happens if the vacuum energy density (energy density has the same units as pressure, N/m^2) is integrated over the light horizon radius of the observable universe, or more simply over the surface area of the "COBE Sphere" with a radius of 13.7 billion light years? See Figure 1 for a cartoon depiction.

The vacuum energy density has been measured to be approximately 72% +/-3% of the critical density, r0, or rather 0.72 * 9.9x10-27 kg/m3, based on the apparent brightness of supernovae at red shifts of z ~ 1. The result is rather startling and can be re-arranged

such that the gravitational constant can be shown to be a long wavelength consequence of the quantum vacuum rather than a fundamental constant. In this view, gravitation is an emergent force from the vacuum, and not a fundamental fourth force. The following equation is the more formal version that is produced after some effort from the cosmological Friedmann equation.

$$G = \left(4\pi \cdot t_H{}^2 \cdot \frac{2}{3} \rho_0 \right)^{-1}$$

It was just shown how the gravitational constant can be a long wavelength (Hubble time, tH) consequence of dark energy, or rather the quantum vacuum. It can be similarly shown that the Planck constant has a unique relationship with the Hubble time and dark energy by means of the Einstein tensor. In this instance, consider the 00th element corresponding to the energy density of space-time of the Einstein tensor for the same observer discussed earlier:

$$G^{\mu\nu} = R^{\mu\nu} - \tfrac{1}{2} g^{\mu\nu} R = -8\pi \frac{G}{c^4} T^{\mu\nu}$$

A quick note on nomenclature, the G with indices is the Einstein tensor, while the G without indices is the gravitational constant. After some work (which is omitted for brevity), it can be shown that the following relationship is numerically true:

$$G^{00} = \frac{-2}{c^2 t_H{}^2} = \frac{-h\upsilon_0 K}{4\pi}$$

The G00 element of the Einstein tensor produces the Planck constant times the lowest observable frequency, ṽ0. The constant, K, is of numerical value unity but with units of Joules-1*meter-2 for dimensional consistency. To illustrate the significance of this finding, the equation can be rearranged as follows (K omitted for clarity):

$$h = \frac{8\pi}{c^2 t_H}$$

All of this work is meant to illustrate the point that two physical constants, the gravitational constant G and the quantum mechanics physical constant h can both be shown to have a common mathematical/fundamental relationship to dark energy, or the quantum vacuum. Are there other characteristics of the quantum vacuum that give some insight on how to address the pinnacle objective of actually using it as a propellant source? Some more theoretical work must be presented to further frame the discussion. In Obousy's investigation into Casimir Energies and Phenomenological Aspects, it was shown that the dominant contribution to the density of the quantum vacuum comes from the electromagnetic force (QED Vacuum), by several orders of magnitude over either the electroweak force (Higgs Vacuum), or the strong force (QCD Vacuum). This suggests that it might be fruitful to further explore the electrodynamic characteristics of the vacuum.

But what makes up this quantum vacuum? As was stated earlier, the physics community knows from experiments performed over the last ten years that the vacuum is not empty, but rather a sea of electron and positron pairs that pop into and out of existence as they spontaneously create and annihilate, otherwise known as the quantum vacuum. Interestingly, the Dirac Sea approach (an earlier vacuum model) predicted the existence of the electron's antiparticle, the positron, in 1928. The positron was later confirmed in the lab by Carl Anderson in 1932.

Today, one of the most well known macroscopically observable characteristics of the quantum vacuum is the Casimir Force. Simply put, the Casimir Force is an attractive force between a pair of parallel uncharged metal plates. The Casimir force was first predicted by Casimir in 1948 when he realized that as two parallel uncharged metal plates are moved closer together, they only allow virtual photons of appropriate integer wavelength that fit within the gap between the plates. The net result is to reduce the energy density expectation value between the plates with respect to the free expectation value. Figure 2 demonstrates the concept and identifies the formula relating the pressure between the plates to the physical parameters. The Casimir Force was first tentatively

measured in 1958 by Marcus Spaarnay, and the results generally agreed with prediction. It was subsequently measured more accurately in 1996 by Steven Lamoreaux. A historical, conventional analog to the idea behind the Casimir Force can be drawn considering training given to sailors of the tall-ship era who were instructed to not allow two ships to get too close to one another in choppy seas lest they be forced together by the surrounding waves requiring assistance to be pulled apart.

Figure 2. *Illustration of the Casimir Force*

Uncharged Metal Plates of area, A, and separation distance, d.

Casimir Force, F

$$\frac{F}{A} = -\frac{\hbar c \pi^2}{240 d^4}$$
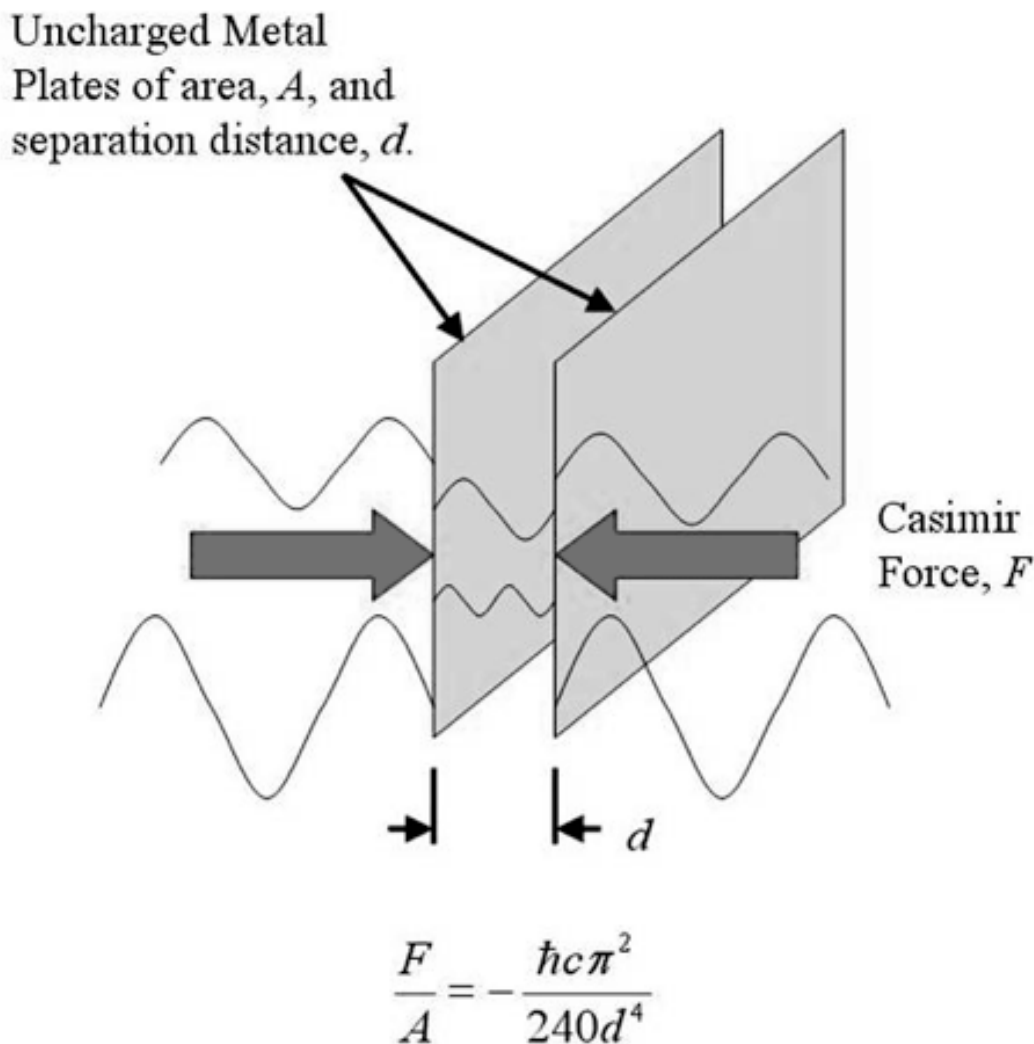
So if the vacuum is never really empty, and the dominant density contribution to the quantum vacuum arises from the electrodynamic force, could the quantum vacuum be treated as a virtual plasma made up of electron- positron (e-p) pairs, and as such have the tools of Magneto-hydrodynamics (MHD) used to model it? If so, then an apparatus could be engineered that could act on the virtual plasma and use it as a propellant. For example, the virtual plasma could be exposed to a crossed electric field E and magnetic field B which would induce a plasma drift vp of the entire plasma in the ExB direction which is at right angles to the first two applied fields. The apparatus would be quite similar in construction to a conventional plasma thrust unit, only it would not need to carry a propellant tank along for the ride. This Quantum Vacuum Plasma Thruster (QVPT) would use the quantum vacuum as its source of propellant, which suggests much higher specific impulses (ISP) are available for QVPT systems, limited only by their power supply's energy storage densities. Figure 3 illustrates the conventional plasma thruster on the left, and a QVPT on the right.

Figure 3. *Plasma Thruster (left) and QVPT (right) are similar except the QVPT need not carry propellant.*
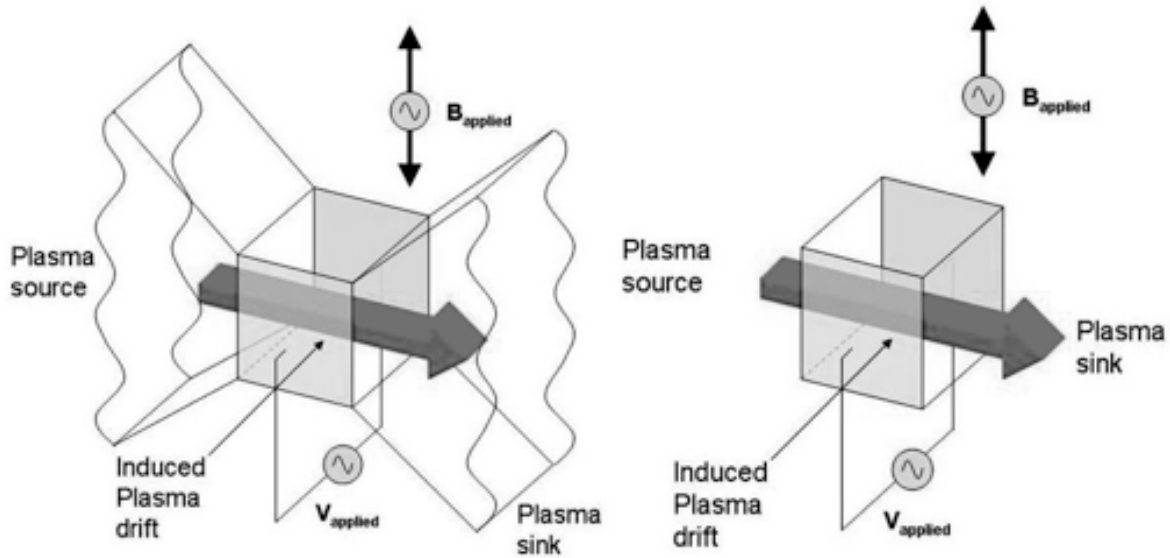
In practice, there are a number of engineering challenges to address, squeezing the vacuum to a density that can be used to produce a thrust that is both observable and useful is of primary interest. The preceeding equations can be used to derive an equation that relates the density (or squeezed state) of the quantum vacuum to local matter density:

$$\rho_{v\_local} = \rho_v \sqrt{\frac{\rho_m}{\rho_v}} = \sqrt{\rho_m \rho_v}$$

In this equation, rv_local is the local density of the vacuum, rm is the local matter density, and rv is the cosmological dark energy density. This equation suggests that a local matter density will result in a squeezed state of the quantum vacuum. The validity of this equation can be checked by considering the ground state of the hydrogen atom. The methodology will be to calculate a quasi-classical density for the hydrogen nucleus using experimental data which will serve as rm, calculate the predicted vacuum fluctuation density rv_local using the equation in question, and then derive the volume (radius) of vacuum energy density necessary to match the ground state of the hydrogen atom.

The ground state of the hydrogen atom is 13.6eV (2.18×10^{-18} N•m) which can be classically thought of as the sum of both the potential energy and kinetic energy for the electron in this orbit. The radius of the hydrogen atom nucleus is given as R0=1.2×10^{-15}m (R=R0•A1/3 where R0 = 1.2×10^{-15}m and A is the atomic number - these are experimentally determined by electron scattering). The radius can be used with the mass of a proton to calculate a quasi-classical density of the hydrogen nucleus:

$$\rho_m = \frac{m_p}{\frac{4}{3}\pi R_0^3} = 2.31 \times 10^{17} \frac{kg}{m^3}$$

Calculate equivalent local vacuum fluctuation density as a function of local matter density present using the dark energy density value ñv=2/3 * 9.9×10^{-27} kg/m3:

$$\rho_{v\_local} = \sqrt{\rho_m \rho_v} = 3.9046 \times 10^{-5} \frac{kg}{m^3}$$

The next step is to determine the volume of this vacuum energy density necessary to sum to the hydrogen ground state of 13.6eV (2.18x10-18 N•m). To the point, what is the radius of the bubble of encapsulated vacuum energy density?

$$r = \left(\frac{E}{\rho_{v\_local} c^2 \frac{4}{3}\pi} \right)^{\frac{1}{3}}$$

The calculated or predicted radius is r = 5.29x10-11m, which turns out to be an exact match to the given value for the Bohr Radius, a0 = 5.29x10-11m. In the process of checking the validity of the equation, we have just derived the Bohr radius as a consequence of cosmological dark energy, and that the dark energy fraction should be exactly 2/3 in lieu of the 0.72 +/- 3%. Readers familiar with the history of the development of quantum mechanics will recognize the profound implications of the above findings.

Are there other methods by which the squeezed state of the vacuum can be altered to be of benefit as a propellant source? To answer this question, consider the extragalactic magnetic field which is estimated to be 1x10-12 Tesla. If the quantum vacuum can be treated as a virtual plasma, then the magnetic energy density (or pressure) should correlate to the plasma pressure. The magnetic pressure is calculated using the following equation: PB = B2/(2m0), B = 1x10-12T, m0 = 1.26x10-6 T2m3/J, PB = 3.98x10-19 N/m2. The plasma pressure can be calculated using the following equation: Pplasma = nekT. The electron-positron density ne can be found using ne = rc/me. The critical density is as stated before, rc = 9.9x10-27 kg/m3, and the temperature is T = 2.73K. Assuming an e-p plasma population, the plasma pressure is Pplasma = 4.09x10-19 N/m2.

This relationship suggests that in the far field limit, the magnetic field squeezes the quantum vacuum. This same methodology can be applied to dark matter models for galaxies to see if there is a similar correlation when treating dark matter as a virtual e-p plasma. Current dark matter models for galaxies can be used to predict a galactic halo magnetic field as a function of galactic radius, and this magnetic field magnitude distribution can be compared to observation. Although galactic halo magnetic field strength and structure is not fully understood, the predictions can still be compared to the data and models available. Figure 4 shows the comparison. As with the extragalactic magnetic field, there is a very strong correlation for the galactic magnetic field. As a matter of caution, when considering conventional magnetic field strengths, Temperature must also be incorporated into the model. These findings also show that the tools of MHD can successfully be used to model quasi-classical behavior of the vacuum.

Figure 4. Galactic Halo Magnetic Field
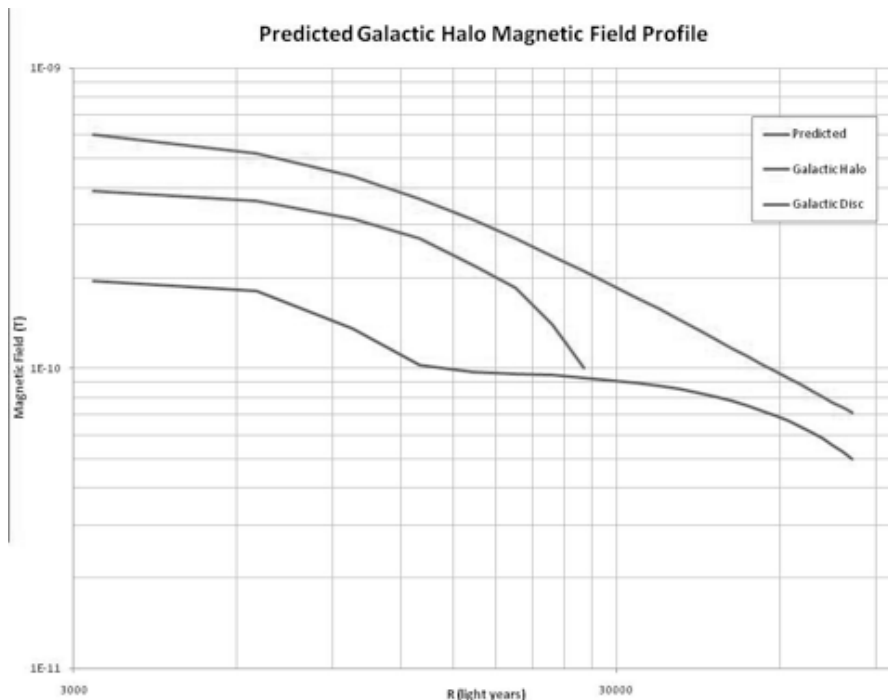
A spectrum of high fidelity engineering tools have been developed to design and implement several thruster units for testing purposes. As it turns out, there are multiple input parameters that exhibit inherently nonlinear behavior when calculating thrust expectations. In many cases, certain input parameters work against one another in the process of trying to optimize a point design solution. Geometry, dielectric material, drive frequencies, peak field strengths, phase angles, and more have to be balanced for a given construction to provide predictions that are observable. To date, possible thrust levels in the 1000-3000 microNewton range have been observed with an equivalent specific impulse of 1×10^{12} seconds. Figure 5 depicts a test unit and a thrust trace. To clearly establish the phenomenon, its scaling behavior, and make this technology relevant to the commercial satellite sector, the next test article currently under construction was designed to produce a thrust in the 0.1 to 1 Newton thrust range with an input power of ~1kW. Figure 6 shows the thrust predictions as a function of input power with an inset of the test article at the top left of the figure.

Figure 5. 1000-3000 microNewton class thruster with thrust trace
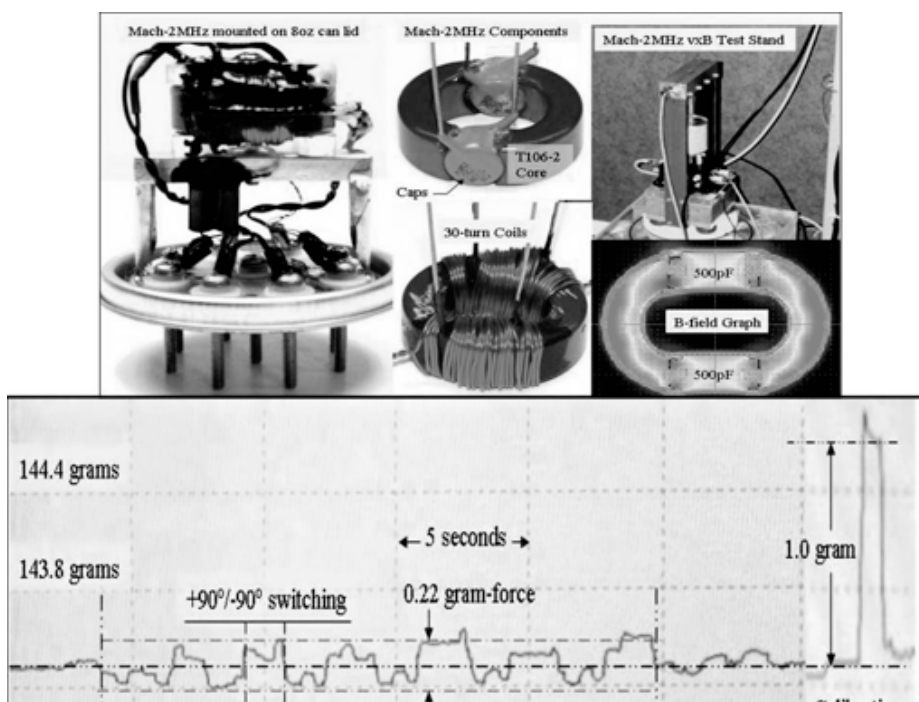
At this point, a few words should be spent to address the question of how the quantum vacuum communicates momentum information across a boundary constraint. For example, consider momentum information that has been imparted on a squeezed state of the vacuum by means of the noted crossed E and B fields within an enclosed region. The quantum vacuum is continuous, but has different density depending on multiple input parameters just discussed, one being the density of conventional matter such as the copper walls of a resonator unit. As the momentum information moves through this barrier, the density of the quantum vacuum within the copper walls is many orders of magnitude less than the squeezed state inside the enclosed region meaning any momentum information lost through a "collision" process with the copper lattice is many orders of magnitude less than the total momentum information gained by the source of the electric and magnetic fields (the copper thrust chamber). This means the departing momentum information will have a long range effect as the quantum vacuum field carrying this information is very weakly interacting with conventional matter due to the very low quantum vacuum densities. This is why we still feel gravity even though we put a thick plate of steel between us and the earth. A gravity well is a hydrostatic pressure gradient in the quantum vacuum, while a QVPT is a hydrodynamic pressure gradient in the quantum vacuum.

If the experimental effort can demonstrate that the thrust magnitude can be scaled to the 0.1 to 1 Newton range with an input power of ~0.1 to 1 kilo-Watt, this would establish the market entry-point for this technology. High power Hall-Effect Thrusters are used as station-keeping thrusters providing 0.5 to 1 Newton of thrust with 7 to 20 kilo-Watts of input power. Is there a business case that can adapt and employ the QVPTs to benefit the commercial satellite sector? Consider the following hypothetical business case.

Currently, there are 40-80 mini-satellites (~1000 pounds) per year that could utilize QVPTs in this size and power budget (see the Futron presentation, If you build it, who will come, presented to the 22nd AIAA/USU Conference on Small Satellites). If the test article were to generate the desired thrust levels, it is estimated that it would take about two years and approximately $10 million to design the first flight article. By producing equivalent thrust at a lower input power requirement, this would allow satellite designers to reduce the size of solar panels and thermal management systems. This translates into cost savings for satellite designers based on an industry metric of ~$500 per Watt. The power budget for a 0.1N Hall-Effect thruster would be ~ 1500 Watts, while an equivalent thrust level QVPT ~200 Watts, yielding a net savings of 1300 Watts power for a QVPT-equipped satellite design. This would result in a potential savings of ~$650K in the final design due to reduction in overall power level and reduced thermal management system. Assume that the flight QVPT articles could be manufactured for ~$500K per copy, and sold for ~$750K. The satellite designer saves the $650K in reduced thermal and power systems, and saves the cost of the equivalent Hall-effect thruster that was replaced by the QVPT, minus the $750K to purchase the QVPT. The net result is that the satellite manufacturer effectively gets a high performance engine for $100K. With these rough metrics, the design can become profitable within roughly forty sales, which is reasonable considering the annual market and cost savings for customers.

Figure 6. 2.45 GHz QVPT thrust predictions versus input power
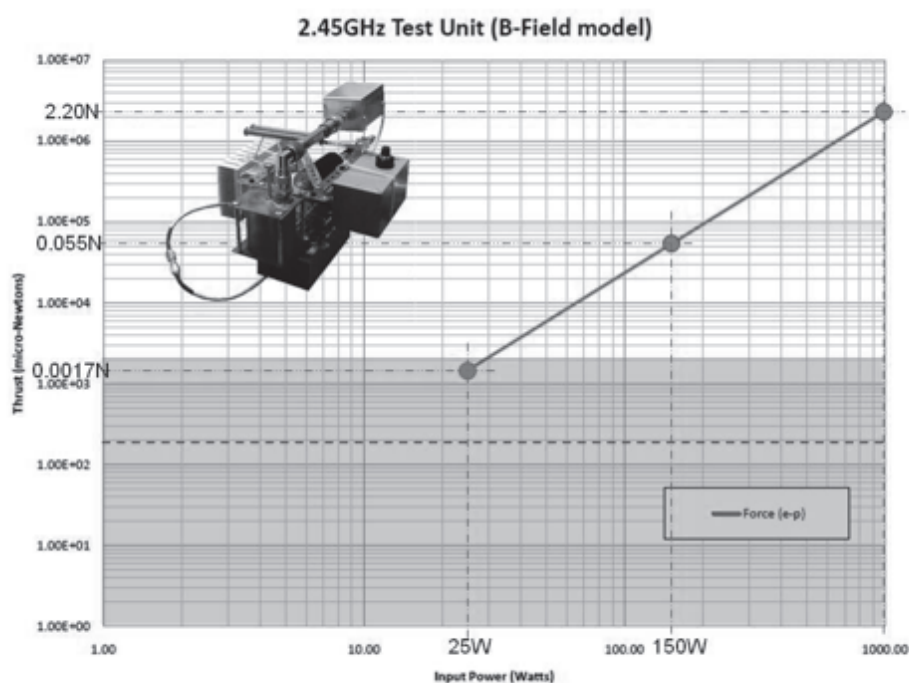
Note that in the above brief business case, we did not make use of the ultra-high ISP for the QVPTs, which will also result in the beneficial characteristics of the satellite system: A QVPT-equipped satellite can maintain position for life of hardware with no propellant limitations. Satellite missions can include servicing multiple orbits and inclinations which are precluded with other systems. Earth monitoring satellites and communications satellites could maintain a parked position in GEO, and change to different altitudes and/or inclinations based on transient and unpredictable events. Although this case study dealt with QVPTs, most forms of advanced propulsion research can likewise be shown to have beneficial characteristics back here at home. While the mention of advanced propulsion may invoke pictures of plucky little probes or vast crewed-spaceships headed off into the great unknown, advanced propulsion research can produce technology that can be matured within the crucible of the terrestrial commercial/civil/ defense satellite sector. Thus the argument can be made that advanced propulsion research will not produce myopic point solutions with little-to-no intrinsic domestic value, rather these solutions will greatly improve the abilities and robustness of local space assets, while at the same time producing mission-enabling technology. ■

Dr. Harold White **currently serves as the Space Station Remote Manipulator System Manager for NASA in the Engineering Directorate at the Johnson Space Center. He is also a recognized expert and advocate of advanced propulsion research.**

DREAM – An ISU Space Studies Program Team Project for Disaster Risk Evaluation and Management

by G. Dyke, E. Anderson, R. Davies, F. Betorz, A. Bukley , C. Aas, J. Cackler, W. Dos Santos, K. Dunlop, and C. Toglia

Introduction

In the summer of 2009, forty eight researchers, students, and professionals from twenty four different countries formed a team to work on the International Space University (ISU) Disaster Risk Evaluation And Management (DREAM) Project. The DREAM Project teamed up with NASA Ames Research Center and the World Bank to address the use of space technologies to aid in disaster risk management in Belize as part of the International Space University Space Studies Program. Executed at a blistering pace with a start-to-finish time of less than six weeks, our team managed to successfully interface with three satellite companies and the Belizian government to acquire data, weigh the relative effectiveness of different measures and strategies, and analyze the legal considerations and potential sources of funding for the recommendations made. The project was a resounding success, and will continue to effect policy in Belize, and hopefully, other regions around the world in need of disaster risk management (DRM) programs in years to come. The project's focus on using space, airborne and ground-based technologies to aid the world's less fortunate is very much in line with the missions of the American Astronautical Society, and we look forward to further interactions in years to come.

DREAM´s Scope

The main task of our project was to provide recommendations to the World Bank on disaster risk management. In particular, the DREAM project investigates how existing Earth observation technologies and information technologies could be combined with DRM initiatives like CAPRA (Comprehensive Approach to Probabilistic Risk Assessment). The result of this project was named CAPRA 2.0 as shown Figure 1. CAPRA is a disaster risk analysis project launched in 2007 by the World Bank, IDB (International Development Bank), EIRD (Estrategia Internacional para la Reducción de Desastres) and CEPREDENAC (Centro de Coordinación de la Prevención de Desastres Naturales en América Central) with the objective of producing risk maps and financial risk transfer strategies for decision makers to manage risk at local and national levels. The CAPRA architecture has been developed to be "modular, extensible and open, allowing it to be expanded and improved. This enables the creation of a "living instrument' where experience is accumulated rather than lost, harnessing the collective work of contributors."

How DREAM Works

Our ultimate goal, and the ultimate goal of DRM in general is to reduce human and economic losses mainly in developing countries that are vulnerable to natural disasters. In order to meet this requirement, the DREAM process workflow relies on three sources of data, as shown in Figure 2, satellite technologies, airborne technologies, and ground-based technologies.

Some of the major recommendations we made included extending the current CAPRA project to include road maps for a legal framework concerning data ownership and public outreach. The
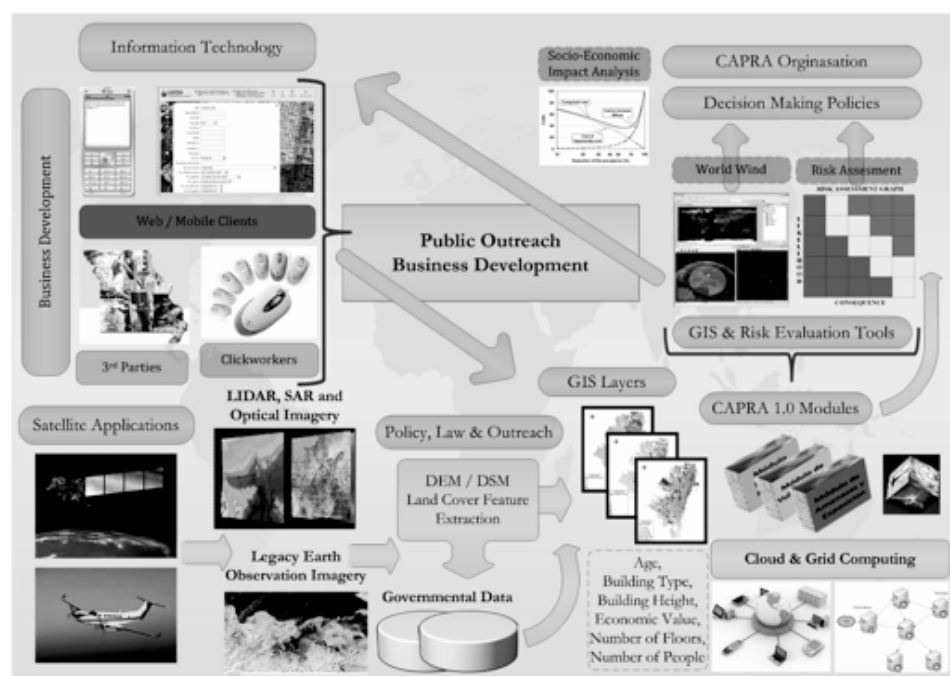

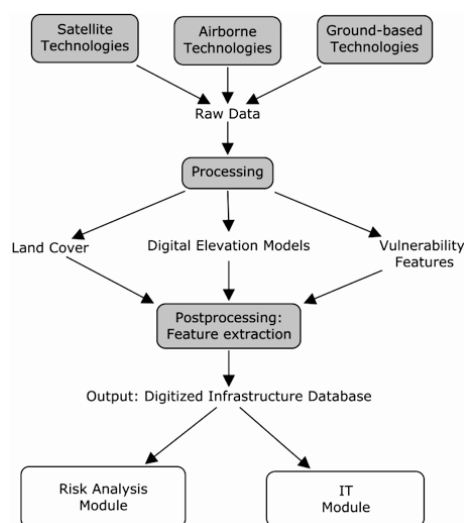**Figure 1.** *The CAPRA 2.0 System Architecture*

Figure 2. DREAM Process Workflow

CAPRA project has developed an open source platform that can be extended by its users and allows them to evaluate disaster risks by modeling hazards while accounting for vulnerability and exposure to disasters in a particular geographical region. It currently focuses on Central America. We chose to focus on Belize for a number of reasons. As the smallest country in population, Belize is a great test platform for DRM strategies. Additionally, the government of Belize expressed great interest in working with CAPRA and the DREAM Project on this issue. Belize further shares many commonalities with both Central American and Caribbean countries, and so the lessons learned in Belize can be broadly scaled. Finally, much of the population of Belize is on the coast or near rivers, and so a large proportion of the population of Belize is vulnerable to hurricanes. While we focused on Belize, the risk mitigation strategies that are proposed can be extended beyond Central America.

Project Outcomes

Based on the research carried out during the DREAM project, we made a number of recommendations for future work and the continuation of the project. The recommendations are primarily in the areas of risk evaluation (including risk analysis and satellite applications), computer applications, business development, public outreach, and policy and law.

Our project helped establish a historical imagery database in order to build a reference heritage. Data collected from satellites, ground sensing, and potential LIDAR missions provided indicators for quality verification in the modeling and prediction aspects of the CAPRA tools. Finally, we recommended the establishment of dedicated post processing modules to broaden services to specific users. The continuity plan of the business development research is focused on knowledge transfer. We identified the insurance sector as a fundamental collaborator in the long-term. Capital gained through the sale of DRM data to insurance companies and other commercial entities can be reinvested in purchasing more data sets for CAPRA's use, and in providing the CAPRA program and data sets to developing countries at a subsidized rate.

The most important legal issue that was identified for CAPRA was the necessity to develop 'Terms of Usage' to clarify the ownership of CAPRA and how it may be used (akin to a code of conduct). Another significant improvement that may facilitate greater interest from the space industry would be the development of a mature organizational structure for CAPRA. In terms of public outreach a global 'certificate' can be established to recognize the efforts of countries in the field of DRM to create a standard level of preparedness for countries to follow, and provide an incentive for a country to work towards an internationally visible status.

We developed a mobile-based application for iPhone, using it as a technology demonstration platform to show the feasibility of the collection and submission of exposure ground data from the field. In future the application should be extended to include access to satellite imagery and maps to aid the user to correctly input information, and can be adapted to other platforms as use cases develop. Moreover, it should be possible to select which CAPRA databases to use.

Regarding technology, the use of service-oriented architecture for CAPRA should be evaluated to provide inter-operability and improve accessibility. The development of a dissemination mechanism in the future, where the user can register to receive information via sms/email about disasters near the user's current location or area of interest, would be a significant contribution to the disaster response phase following DRM.
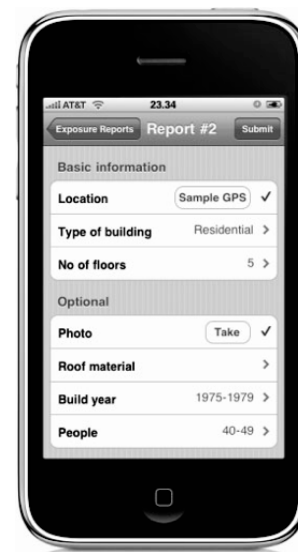
Figure 3. iPhone Application

Final Remarks

Developing this project in such a short time scale was a tremendous undertaking, but the results speak for themselves. Our recommendations are already being carried out, and we eagerly anticipate seeing some of our more long-term recommendations being put into action in Belize, Central America, and the world. Moreover, we look forward to seeing increased interaction between private space industries, public research organizations, non-profit organizations, and national and local governments, to use developing technology to aid those who need it most. For more information please refer to www.symphora.org. One of the greatest gifts that technology that we have developed to explore the heavens has given us is the ability to save our own planet.

The International Space University, the 'gold standard in interdisciplinary space education', is a graduate school that conducts programs at its central campus in Strasbourg, France, and at locations around the world. ISU offers a unique core curriculum covering all disciplines related to space programs and enterprises – space and earth sciences, engineering, satellite applications, policy and law, business and management, and space and society. ISU also provides short courses for professional development and life-long learning.

Since its founding on the campus of MIT in 1987, with noted author and visionary Sir Arthur C. Clarke as its first Chancellor, ISU has graduated more than 2900 students from 100 countries, many now in senior positions with commercial and government space-related organizations throughout the globe.

For further information on the International Space University: www.isunet.edu; further information on this and other ISU team projects, and for download, please go to: www.isunet.edu/publications/student_reports. (© International Space University 2009)

Team Project Authors

Christina Louise Odette Aas
M.Sc. Space Systems Engineering
NORWAY

Tiago L. Alves
M.Sc. Software Engineering
PORTUGAL

Yngvild Linnea Andalsvik
Ph.D. Student Space Physics, University of Oslo
NORWAY

Li Benjin
China National Satellite Ocean Application Service
CHINA

Eyal Ben-Ze'ev
Israel Aerospace Industries Space Division
ISRAEL

Beatriz Garcia Bernal
M.Sc. Telecom. Eng., European Space Agency
SPAIN

Vincent Beukelaers
M.Sc. Aerospace Engineering, University of Liège
BELGUIM

Ludivine Boche-Sauvan
Arts et Métiers ParisTech & GeorgiaTech
FRANCE

Jack Cackler
M.Sc. BioEng., Stanford University, KAUST
USA

Marline Claessens
M.Sc. Technical Lead System Engineer, Verhaert Space
BELGUIM

Manuel Antonio Cuba
B.Sc. Industrial Eng., ISU 2010 M.Sc. Student
PERU

Thierry David
French Air Force Officer
FRANCE

Thibault Deleu
Free University of Brussels
BELGUIM

Marc D'oriath
French Air Force Engineer Officer
FRANCE

Walter Abrahao Dos Santos
Brazilian National Space Research Institute (INPE)
BRAZIL

Nitant Dube
Indian Space Research Organization
INDIA

Kathryn Dunlop
B.Sc. Physics, University of St. Andrews
UNITED KINGDOM

Ivo Ferreira
Ph.D. Student, Aerospace Engineer
PORTUGAL

Noam Ganot
Senior Systems Engineer, Israel Space Program Office
ISRAEL

Rebeca Martinez Gil
Ground Station System Eng., Makalumedia Group
SPAIN

Xiaohong Gong
China Aerospace Science and Technology Corporation
CHINA

Yanne Francois Haugrin
French Space Agency - CNES
FRANCE

Heather L. Heine
Ph.D., MD Cand. 2011, Uni. of British Columbia
CANADA

Fatoumata Kebe
Université Pierre et Marie Curie
FRANCE

Elisabetta Lamboglia
M.Sc. Space Sys. Eng., Heerema Marine Contractors
ITALY

Yoshinori Matsubara
Ph.D. Student, Aerospace Eng., Tohoku University
JAPAN

Joshua Nelson
SEDS
USA

Viktor Nikolaidis
M.Sc. Mobile & Satellite Communications (UniS)
GREECE

Thomas Paullier
Payload Design Manager, EADS Astrium Satellites
FRANCE

Daniela Petrova
Ph.D. Student, University College London (UCL)
UNITED KINGDOM

Andreas Pollinger
PhD Student, Space Research Institute (IWF)
AUSTRIA

Ole Gammelgaard Poulsen
B.Sc. Elec. Eng., Technical University of Denmark
DENMARK

Aku Riihelä
Researcher, Finnish Meteorological Institute
FINLAND

Mauro Tadao Sakita
Brazilian National Space Research Institute (INPE)
BRAZIL

Syed Shere
Program Manager, Comdev International, Canada
CANADA

Seiji Shiozawa
B.Sc. Mech. & Control Eng., Kyushu Inst. of Tech.
JAPAN

Stanislaw Ostoja Starzewski
M.Eng. in Computer Engineering & Science
POLAND

Sudhira Subbaiah
Indian Space Research Organization
INDIA

Takahiro Sumida
B.Sc. Elec. Eng., Kyushu Institute of Technology
JAPAN

Naoyuki Tahara
B.Sc. Mech. Eng., Kyushu Institute of Technology
JAPAN

Fabien Tessier
Snecma - Space Engines Division
FRANCE

Chiara Toglia
University of Rome "La Sapienza"
ITALY

Johan Tresvig
Electrical Engineer, University of Oslo
NORWAY

Nicolas Verstappen
M.Sc. Aeronautics & Aerospace, VUB, CNES
BELGUIM

Yan Wang
China Aerospace Science and Technology Corporation
CHINA

Lei Zhan
China Aerospace Science and Technology Corporation
CHINA

20TH AAS/AIAA Space Flight Mechanics Meeting

The 20th Space Flight Mechanics Meeting will be held February 14–17, 2010, at the San Diego Marriott Mission Valley in San Diego, California. The conference is organized by the American Astronautical Society (AAS) Space Flight Mechanics Committee (SFMC) and co-sponsored by the American Institute of Aeronautics and Astronautics (AIAA) Astrodynamics Technical Committee. Further details and registration may be obtained at http://www.space-flight.org. The conference will cover topics related to space flight mechanics and astrodynamics, including but not limited to:

- Artificial and natural space debris
- Asteroid and non-Earth orbiting missions
- Atmospheric re-entry guidance and control
- Attitude dynamics, determination and control
- Dynamical systems theory as 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 dynamics, perturbations, and stability
- Satellite constellations
- Spacecraft guidance, navigation and control
- Rendezvous, relative motion, proximity missions, and formation flying
- Trajectory / mission / maneuver design and optimization

BREAKWELL STUDENT TRAVEL AWARD

The AAS Space Flight Mechanics Technical Committee also announces the John V. Breakwell Student Travel Award. This award will provide travel expenses for up to three (3) US and Canadian students presenting papers at this conference. Students wishing to obtain this award are strongly advised to submit their completed paper by the abstract submittal deadline to allow for judging. The maximum coverage per student is limited to $1,000. Further details and applications may be obtained at http://www.space-flight.org.

SPECIAL EVENTS

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Monday – Brouwer Award Lecture, Awards Ceremony, and Reception
Tuesday – San Diego Zoo Animal Show and Dinner Social Event

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Dr. Aaron Trask
Apogee Integration
5180 Parkstone Drive, Suite 160
Chantilly, Virginia 20151
703-808-0609 (voice)
atrask@apogeeintegration.com

AAS Technical Chair
Dott. Daniele Mortari
Texas A&M University
Department of Aerospace Engineering
H.R. Bright Building, Room 611C
Ross Street, TAMU 3141
College Station, TX 77843-3141
979-845-0734 (voice)
979-845-6051 (fax)
mortari@aero.tamu.edu

AIAA General Chair
Mr. James K. Miller
19265 Braemore Road
Northridge, CA 91326
818-488-1873 (voice)
jkm1997@verizon.net

AIAA Technical Chair
Dr. Thomas F. Starchville, Jr.
The Aerospace Corporation
MS CH4-500
15049 Conference Center Drive
Chantilly, VA 20151
571-307-4203 (voice)
571-307-4217 (fax)
thomas.f.starchville@aero.org
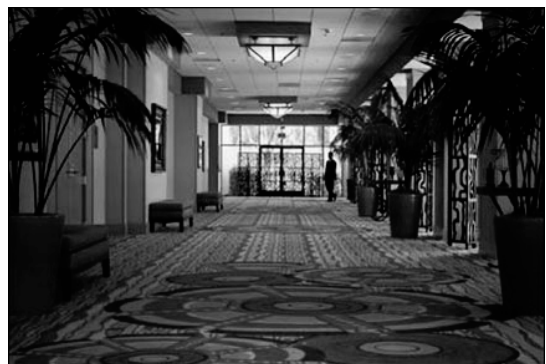
AAS Events Schedule

February 5-10, 2010
AAS Guidance and Control Conference
Beaver Run Resort and Conference Center
Breckenridge, Colorado
www.aas-rocky-mountain-section.org

February 14-17, 2010
*AAS/AIAA Space Flight Mechanics Winter Meeting
Marriott San Diego Mission Valley
San Diego, California
www.space-flight.org

February 23-26, 2010
SPESIF-2010: Space, Propulsion & Energy Sciences International Forum
JHU/Applied Physics Laboratory
Laurel, Maryland
www.ias-spes.org

March 10-11, 2010
48th Robert H. Goddard Memorial Symposium
"Earth and Beyond: The Next Decades"
Greenbelt Marriott
Greenbelt, Maryland
www.astronautical.org

May 17-19, 2010
Kyle T. Alfriend Astrodynamics Symposium
Monterey Plaza Hotel & Spa
Monterey, California
www.space-flight.org

June 11-13, 2010
*6th Student CanSat Competition
Amarillo, Texas
www.cansatcompetition.com

August 2-5, 2010
*AIAA/AAS Astrodynamics Specialist Conference
Sheraton Centre Toronto
Toronto, Ontario, CANADA
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Women in Aerospace

Thank you for your continued support!

International Space University Offers Executive MBA Scholarship

The International Space University (ISU) is offering a major incentive scholarship to select organizations, including the AAS, for the second class of ISU's new Executive MBA (EMBA) program.
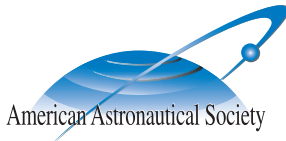
AAS members may apply for an ISU EMBA scholarship at one-third of the 33,000 euro fee for the degree program for this class, which begins in June 2010. A limited number of these one-time scholarships will be awarded, so AAS members are encouraged to apply early.

Webpage for the EMBA program: www.isunet.edu/mba

Inquiries: emba@isu.isunet.edu

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# Energiya-Buran: The Soviet Space Shuttle

Reviewed by James M. Busby

Energiya-Buran: The Soviet Space Shuttle by Bert Vis and Bart Hendrickx. Springer-Praxis Books, 2007. ISBN: 978-0-387-69848-9. $69.95 USD (paperback).

In the late 1980's a popular joke told around the Rockwell Int. offices in Downey, CA where the shuttles were built went: "How do you say Xerox copy in Russian?" Answer- "Buran!" That's what most American's believed when the old Soviet Union first flew their own Space Shuttle system in November, 1988. Rumors of the design of such a system had been flying around here since before the Orbiter "Columbia" first flew in 1981. The American analyst Jim Oberg writing in the AIAA journal, denied that such a system existed the same month that it flew! But the truth of the matter, as always was far stranger. Bart Hendrickx and Bert Vis- who write and help put together the BIS magazine "SpaceFlight" have put together the ultimate text on the Russian Space Shuttle, and few people know about it- even as we are arguing about the demise of the American Shuttle system.

The roots of the Russian system go back to early 1920's and their rocket powered gliders. They had developed their own experimental rocket fighters, but they were given "gifts" in the discovery of the German 346 rocket plane which they mated to a captured American Boeing B-29 Superfortess and conducted flight tests. During the Cold War, they developed their own design of a cruise missile –The Burya, much like the U.S. "Navajo" missile- quickly gave way to the Intercontinental Ballistic Missile. The Russians didn't give up on winged space vehicles even while flying manned (and womaned) space capsules.

This book has many surprises. My first one was a photo of early cosmonauts- including Yuri Gagarin posing with what appears to be late studies model of the modern shuttle orbiter- in 1968?! The Soviets were working on designing many vehicles, including space fighters throughout the 1970's- thinking that the U.S was working on similar systems (like the abandoned X-20 Dyna -Soar). Many like the BOR design were even tested on various launch vehicles and glided to landings in the ocean (where we photographed them).

The book is written by Vis and Hendrickx for the engineer, student or historian with many of what were once state secrets laid out in the open for everyone to study. We discover that the soviets may have copied some concepts and ideas- but spent many millions of Rubles to create a robust, reusable booster and space plane system.
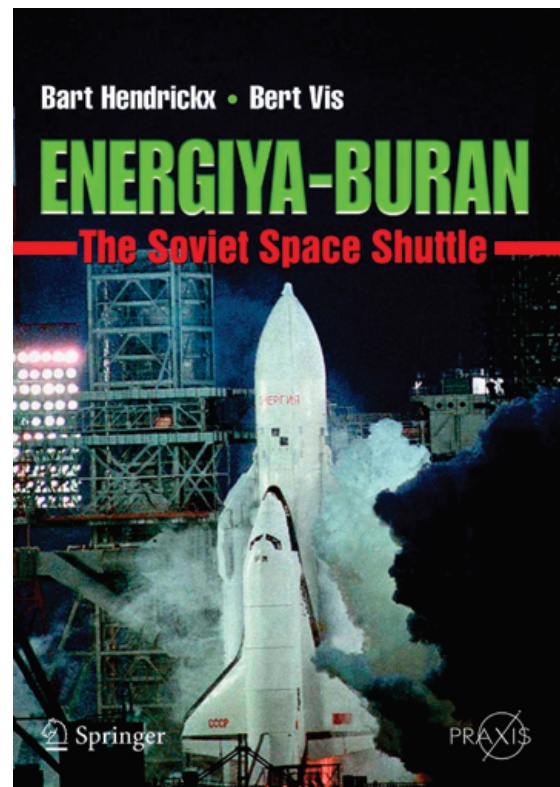
Sadly- The Buran Shuttle Orbiter only flew once unmanned in the final months of the Soviet Union, and fell aside as the Soviet system fell. Parts of them became the 'Sea Launch' system. Its legion of cosmonauts and hardware rusted and then the roof fell in- literally on the huge high bays at the assembly building killing seven people, as well as destroying the only finished hardware and flown orbiter. The plans for super boosters with shuttle orbiters to the Mir 2 space station and missions to Mars died in that building.

While many might groan at the price of a soft cover book, I found it worth every dollar (or pound) you have to pay for it! ■

James M. Busby is Director of Media Relations/Space Historian for the Aerospace Legacy Foundation and a member of the AAS History Committee.

NOTES ON NEW BOOKS

Robots in Space: Technology, Evolution and Interplanetary Travel

Reviewed by Mark Williamson

Robots in Space: Technology, Evolution and Interplanetary Travel by Roger D Launius and Howard E McCurdy. Johns Hopkins University Press, 2008. 313 pages. ISBN: 978-0-8018-8708-6. $35.00 USD (hardback).

The debate over whether manned or unmanned spacecraft are more effective (particularly cost-effective!) in the realm of space exploration has been running almost as long as the Space Age itself. It has led to heated arguments and sometimes, to a lack of willingness to communicate. In a field where communication is essential, such circumstances are at best inadvisable.

This book on unmanned space exploration takes the debate by the horns and labels it "a false dichotomy." "The issue is multi-sided," say the authors, "with approaches like 'manned' and 'unmanned' giving way to less conventional concepts as exploration activities mature." Quite what these "concepts" are is not immediately apparent, mainly because the authors practice a verbosity one usually associates with the social sciences. It later emerges that it has much to do with "geopolitical prestige, and survival of the species." The other three objectives of space exploration presented by the authors – scientific discovery, commercial applications and national security – "can be achieved by robots alone," they say, while some things can only be done by humans. No news there.

The titles of the book's chapters - "Human Spaceflight as Utopia," "Homo Sapiens, Transhumanism, and the Postbiological Universe," "An Alternative paradigm?" – indicate the level of discourse readers should expect. This is no Space-101. This is not to say that the book isn't well written. It's simply not as accessible as some readers may wish. As part of the publisher's "New Series in NASA History," it is aimed more at academics than lay readers (as confirmed by the 45 pages of references and a total lack of illustrations).

Luckily, though, it's an academic book without the academic ($100) price tag, and one of those volumes space aficionados should consider as part of the 'next level.' It's the sort of book you yearn for when you're finished with the coffee table glossies, graduated through the potted histories and the future technology tomes, and feel you're ready for a bit of socio-political analysis and cross-cultural speculation (referring to the "cultures" of science fiction and engineering fact).
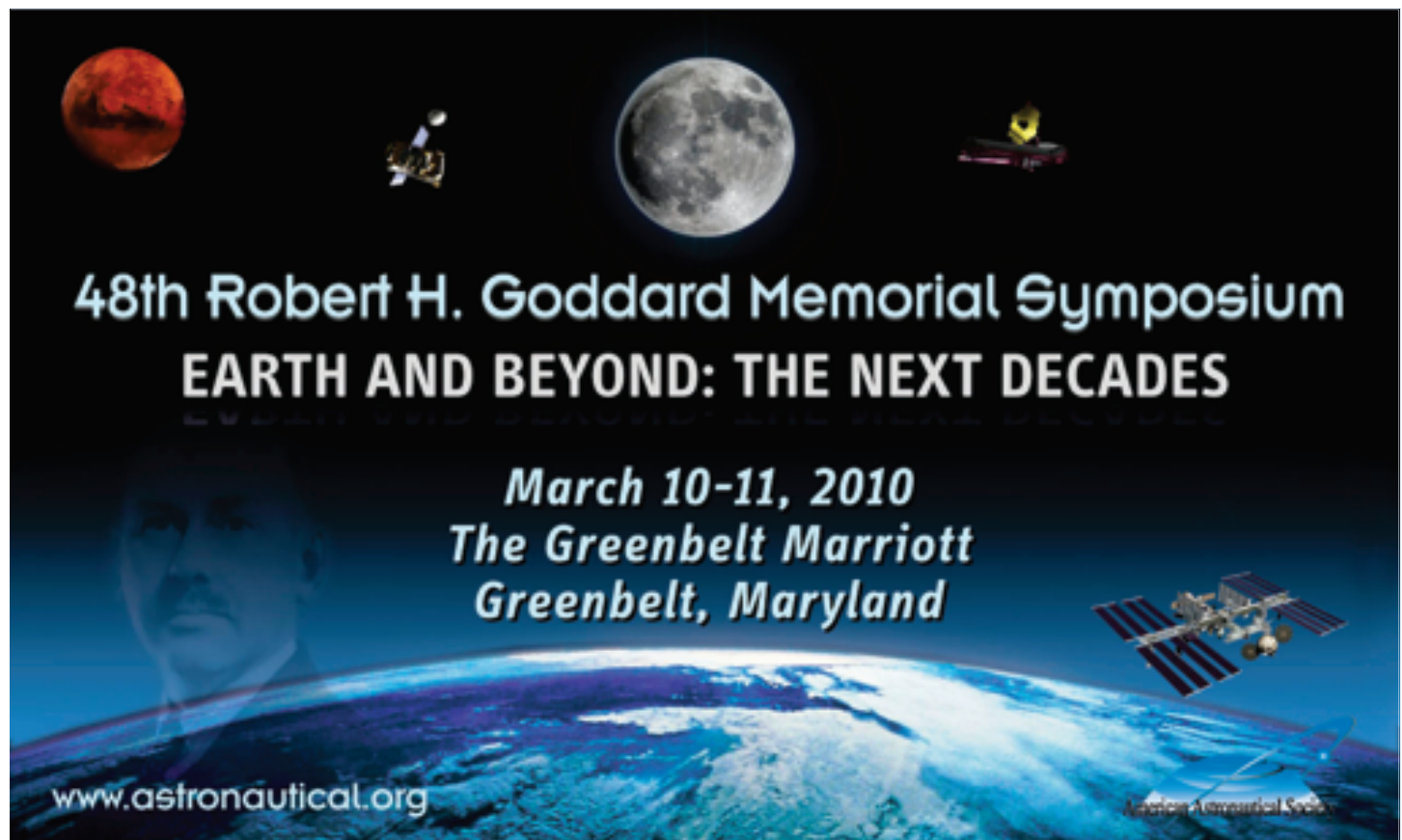
The book contains plenty of references to science fiction, particularly the role of robots, such as "Gort" in the SF classic film *The Day the Earth Stood Still* and what the authors dismiss as "the silly robot in the 1960s television series *Lost in Space*". And of course, you'd be surprised if they failed to mention HAL from *2001*, C3PO from *Star Wars* and Asimov's Laws of Robotics. It is these parts of the book with which most space-aware readers will associate, as they help to place the real-world robotics of space exploration (so far as it exists) in a cultural context.

The difficulty comes when the authors worry themselves about terminology, seemingly uncertain whether to refer to spacecraft as robotic, automated or – in the classical sense – unmanned. They even dedicate an appendix to the subject, titled "Inadequate Words: A Note on Terminology,",which examines the historical development of spacecraft definition. The thing is, they wouldn't have a problem if they weren't so bound up in what they call "an obvious gender impropriety" and recognised that "manned" needn't mean "populated by men."   Modern, intelligent men are well aware of the equality of women, and modern intelligent women don't feel threatened by labels. But this is not the place for discussions of "political correctness." Neither is a book on robots in space.

Ignoring irrelevancies, this book should interest any intelligent reader with an interest in the history and future of space exploration, whatever technology is applied. Its mix of historical background and social context, entirely due to the authors' long experience, takes the reader well beyond the usual issues of technical challenge and budget limitations, while numerous selected quotations accentuate the human element (albeit sometimes by virtue of the technology they produce). For example, former presidential assistant for science and technology, John H Gibbons, compares "the von Braun paradigm – that humans were destined to physically explore the solar system" with "technologies that will fundamentally redefine the exploration paradigm.". "We have the ability to put our minds where our feet can never go," he said. Or as the introduction to *The Six Million Dollar Man* put it so succinctly, "We have the technology." ∎

Mark Williamson is an independent space technology consultant and author.

48th Robert H. Goddard Memorial Symposium
EARTH AND BEYOND: THE NEXT DECADES

March 10-11, 2010
The Greenbelt Marriott
Greenbelt, Maryland

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American Astronautical Society

Program Outline

Tuesday, March 9

Evening Student/Career Reception

Wednesday, March 10

Opening Keynote: Charles Bolden, NASA Administrator - invited

A Users' Guide to NASA's Future, An Introduction

Panel: NASA Headquarters Associate Administrators

Space, NOAA and the New Decade

Luncheon Speaker: Jeff Greason, CEO, XCOR; Member, Review of Human Spaceflight Plans Committee

Panel: Commercial Missions to the ISS

Extreme Space Weather, Logistics, and the Economy

Wrap-up

Evening Reception

Thursday, March 11

Opening Keynote: John Holdren, Director, OSTP - invited

Investments in the Future: NASA's Technology Programs

Panel: Space and Evolution of the Earth

Luncheon Speaker: Esther Dyson, EDventure Holdings - invited
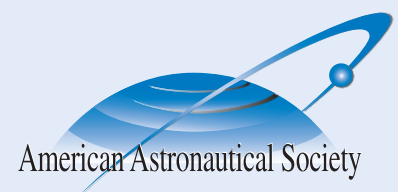
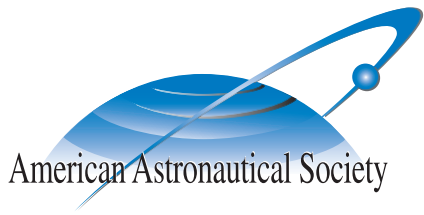Panel: Science and NASA's Human Space Flight Program

Panel: International Goals in Space

Panel: Exciting and Informing the Public

Wrap-up

Closing Reception

American Astronautical Society

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6352 Rolling Mill Place
Suite 102
Springfield, VA 22152-2370

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