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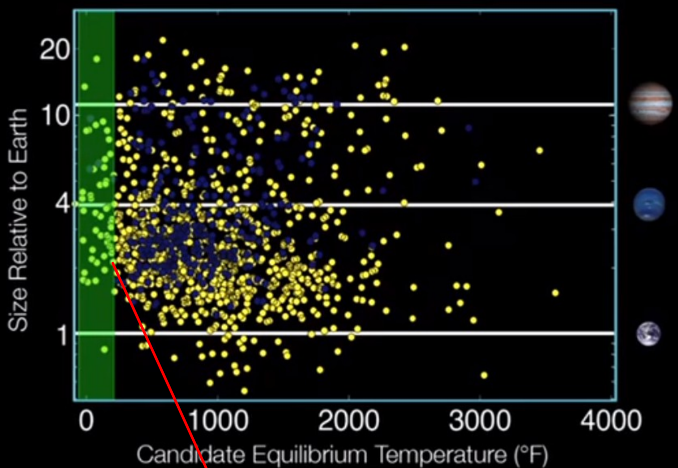
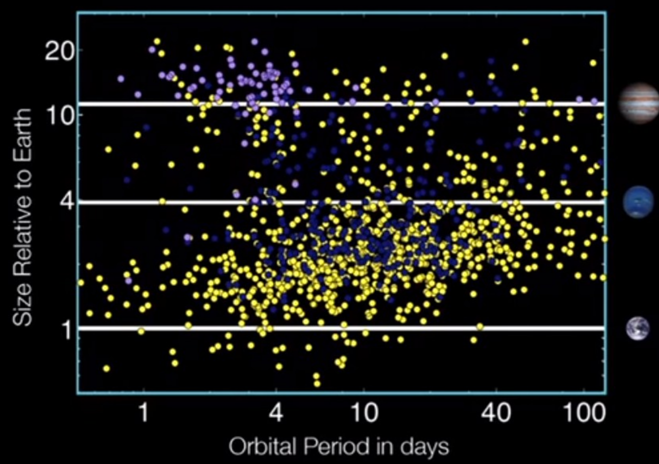
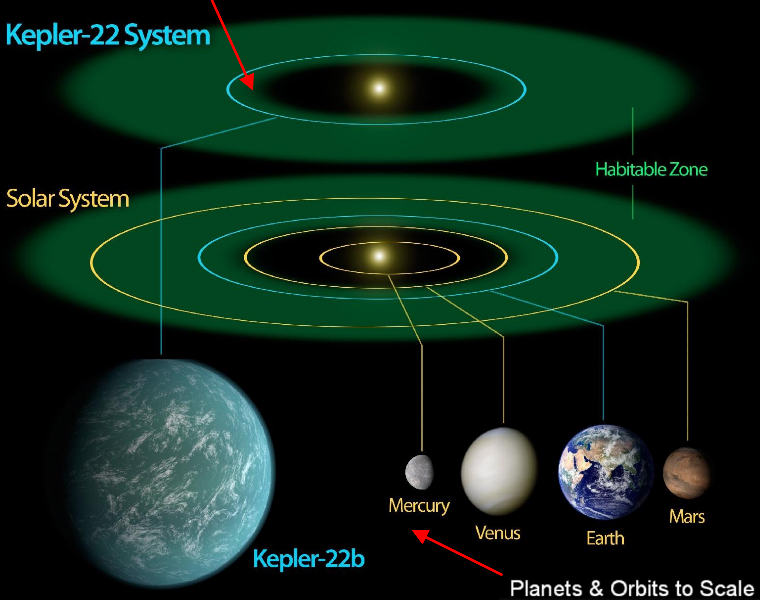
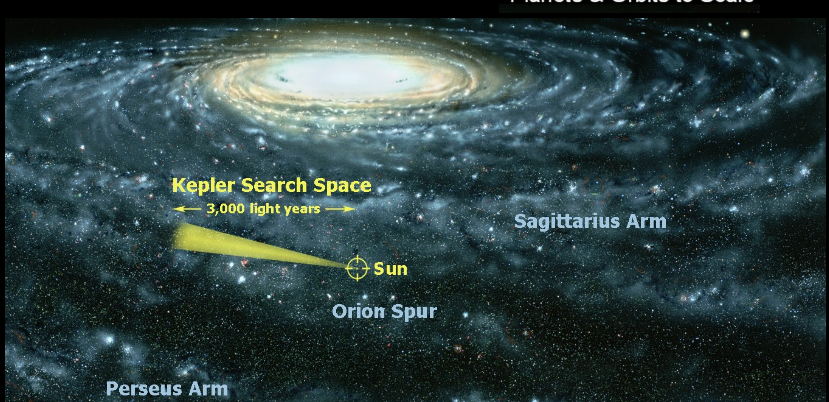
First Confirmation: Planet Kepler-22b
An Earth-Like Exoplanet in a Habitable Zone

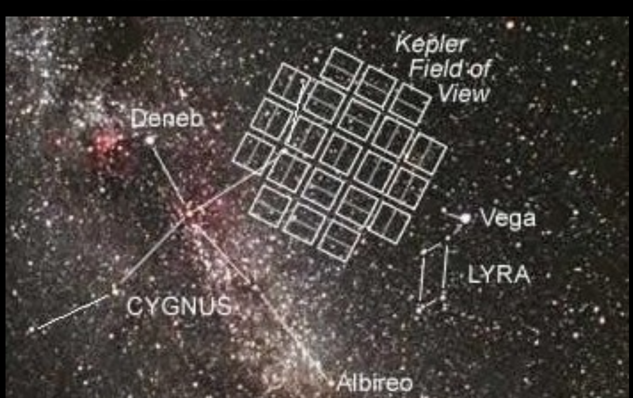
Wes Kelly, Triton Systems LLC











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Cover: Planet Kepler 22-b. Image credits: NASA. Source: NASA press conference of December 5, 2011. Venus transit: Image credit and source: http://blog.urbansedlar.com/wp-content/uploads/2012/02/800px-20040608_Venus_Transit.jpg.

Events on the Horizon

Sean Carter, Chair

Both NASA and the Johnson Space Center community find themselves at a turning point in our history. Last year marked the retirement of the much-heralded Space Shuttle Program and the abrupt cancellation of the Constellation program. These changes meant significant layoffs to our JSC community and many more changes ahead. Many were left confused and pessimistic about the future of human space flight exploration.

Throughout the summer and fall of 2011 JSC Center Director, Mr. Michael Coats, and his staff were aggressively working to study this new environment and chart a new strategic course for JSC. Last month (January 2012), Mr. Coats unveiled his new JSC Strategic Implementation Plan that lays out the 4 JSC Strategic Goals and the success factors required to accomplish those goals. Those goals can be seen below and are further detailed at: http://strategicplan.jsc.nasa.gov/.

As the AIAA Houston Section moves into this bold new future together we are committed to meeting the exciting new challenges and opportunities.

In March, we will be hearing from the principal architect of the JSC Strategic Plan, Dr. Douglas Terrier. Later in March, AIAA will host its Congressional Visits Day on Capitol Hill. In April we'll again host the AIAA Region IV Student Paper Competition aimed at inspiring human exploration in space within our Region IV universities. Finally, in May, we are set to host the AIAA Annual Technical Symposium.

Lastly, likely before summer 2012, SpaceX plans to launch a historic mission where its Dragon Rider will launch on the Falcon 9 from Kennedy Space Center in Florida. Its intention will be to successfully dock the first 100% commercially designed and built US Spacecraft to the International Space Station and, in that moment, usher in the dawn of a new era in commercializing low earth orbit.

From the Chair

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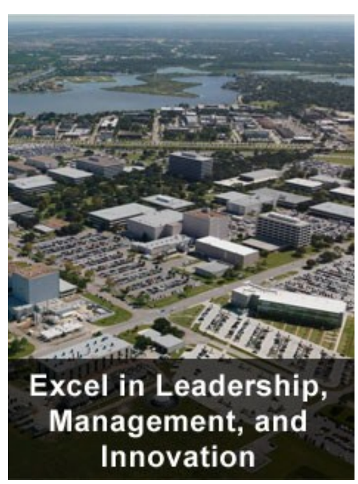
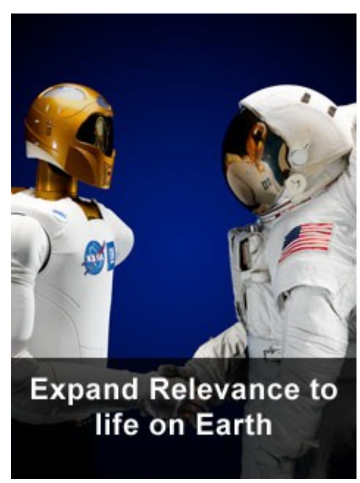
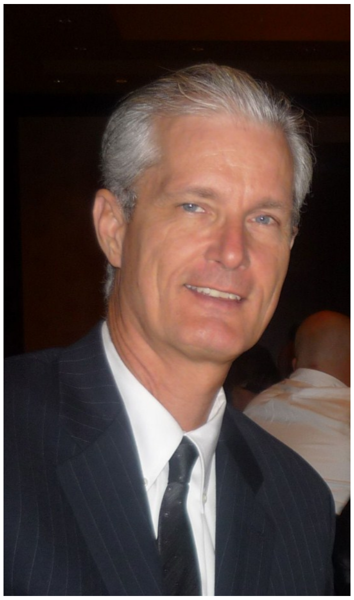




From the Editor



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Our web site www.aiaa-houston.org includes Horizons back issues to 2005 or earlier. For earlier issues (an incomplete archive being slowly updated): https://info.aiaa.org/Regions/SC/Houston/Newsletters/Forms/AllItems.aspx.

Climate Change, Confirmation Bias & Horizons

DOUGLAS YAZELL, EDITOR

Climate change is addressed by presentations at national AIAA events. At our recent dinner meeting (our cover story two issues ago), Congressman Olson stated that NASA should be ordered to stop climate monitoring because, he said, that work is redundant.

The NASA Alumni League Johnson Space Center Chapter (NAL-JSC) is tackling the climate change controversy by fostering a local study group, open to AIAA members, that will focus on available empirical data. Charts from recent presentations at their events are here:

www.nal-jsc.org.

Months after the NAL-JSC events, I watched an episode of Moyers & Company on Public Broadcasting System (PBS) TV with Bill Moyers interviewing social psychologist Jonathan Haidt from the University of Virginia, author of the forthcoming book, The Righteous Mind.

"Reasoning and Google can take you wherever you want to go." is a quote from the book. We all exhibit confirmation bias. Once we make a claim, we stop seeking support for it as soon as we find one nugget of evidence in our favor. Reason is reliable only in diverse groups where our reasoning can be challenged by people we like and respect. Only in those cases will truth emerge. In recent years we rarely spend time in such groups.

One of Professor Haidt's two main messages in this interview is, "Stop demonizing the other side."

Moyers on Haidt: "His ideas are controversial, but he makes you think."

Link to that video presentation as seen on PBS:

http://billmoyers.com/segment/jonathan-haidt-explains-our-contentious-culture/

NASA's Kepler spacecraft continues to inspire with its exoplanet discoveries. Wes Kelly of Triton Systems LLC authors our cover story about planet Kepler-22b.

Thanks as always to our many contributors. I am late with my contributions this time as we work to meet our bimonthly schedule. With luck, I can do this for another year starting July 1, 2012. We always seek new members for our Horizons team, and one day a new editor will be needed.

Above: Image Credit: NASA/NOAA/GSFC/Suomi NPP/VIIRS/Norman Kuring. Image source: http://www.nasa.gov/multimedia/imagegallery/image_feature_2159.html

Above: Responding to public demand, NASA scientists created a companion image to the wildly popular 'Blue Marble' released last week (January 25, 2012). Credit: NASA/NOAA

Planet Kepler 22-b: An Historic Discovery

WES KELLY, TRITON SYSTEMS LLC

Finally, we've got one: an extra-solar planet (an exoplanet) in a habitable zone (the green zone in the cover illustration) near to Earth in size. By the time this article is published, we expect significant additions to the Kepler Observatory planetary detection list. But at this writing (January 2012), with some deserved fanfare, but not the fanfare which centuries of speculation and decades of work might have inspired, it was announced (05 December 2011) that a far-off planet resembles Earth more than any others found so far. Orbiting within its sun's region of thermal habitability (see cover illustration), with a diameter 2.4 times that of Earth's, planet Kepler-22b lies 620 light years or 190 parsecs away. Its sun is a G5V star, slightly less luminous than our Sun in the constellation of Cygnus the Swan. We know this because it transited in front of its primary several times during Kepler's science observations, exhibiting an orbital period of 290 days. Of planets so far detected beyond the solar system, this is the one where water's presence has the best chance to mean precipitation, oceans and lakes. Or it could be just another illustration of how much different a world could be with larger girth, extra core or a different raindown of volatile compounds during formation. We have still much more to learn about the implications of "super-Earths" with diameters 1.25, 2.0… or 2.4 times as wide as Earth's diameter.

The Kepler spacecraft mission is to find what percentage of stars in our galaxy host Earth-like planets in thermally habitable zones. But the estimate needs to be drawn from statistical study of planets of a variety of sizes and distances from their stars. The Kepler team defined "super-Earths" as extra-solar planets with diameters up to twice Earth's diameter. Neptune has a diameter about four times that of Earth's and in the Solar System it is next after Earth in ascending order of size among the planets. Neptune sets the diameter limit of the next category of planets in which Kepler-22b resides, but this exoplanet lies closer to the super-Earth boundary than to Neptune, and well into the habitable zone.

As reported in December, more than 2,000 possible exoplanets have been detected, most as large as or larger than Jupiter. Several dozen received greater scrutiny, either because they resided in the habitable temperature zone of their parent stars, they resembled the Earth in their dimensions or mass, or they exhibited other remarkable features. This last category included densely populated stellar systems and a planet in orbit about a pair of stars (a stellar binary). Based on the statistical data derived from the Kepler Observatory monitoring 150,000 stars since 2009 for planetary transits, one study calculated that "there ought to be about 23 Earth-size planets for every 100 Sun-like stars" (Wall Street Journal - 21 Dec. 2011, p. a8). Whether the Sun-like stars are Main Sequence stars in general or perhaps more narrowly defined as spectral type "G", the inference is that there could be billions of such worlds in our galaxy. With the January 2012 American Astronomical Society conference in session in Austin, presenters from the Space Telescope Institute were estimating 100 billion planets in the Milky Way Galaxy.

The detection of extra-solar planets has progressed remarkably in the last two decades. Prior to 1995, attempts to detect planets by position (astrometric) measurements of stars over years of observation (e.g., the case of nearby Barnard's star) were confounded by precision requirements and detected observational biases throwing measurements off. The 1990s breakthrough came with Doppler detection techniques in the visual bandwidth. Planets as large as Jupiter in tightly bound orbits produced radial shifts in stellar velocities of tens or even hundreds of meters per second. Periodic absorption line shifts to higher and lower wavelengths in stellar spectra could be detected above all the other turbulent behavior in the atmospheres of distant suns. From this could be derived a projected radial velocity of an orbiting planet inversely proportional to the star and planet mass ratio factored by the cosine of inclination of the orbit plane to the line of sight (LOS). In most cases the inclination was not known.

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Kepler-22b

Pierre Gassendi
(22 Jan. 1592 – 24 October 1655)

*Figure 2. French philosopher, priest, astronomer, and mathematician. First observer of a planetary transit,
using the calculations of Johannes Kepler. Image credit: Public domain. Image source: Wikipedia.*

(Continued from page 5)

Transit detections were dependent on planets having no LOS orbital inclination. No matter to the observer that the transit was north-south or east-west, it was across the star's observed surface even though from Earth it was little more than a point light source. If the planet was 1/10th the diameter of the star (as Jupiter is in proportion to the Sun), then it would block out 1/100th the light of a uniformly radiant disk; its angular rate of transit giving a clue to when the transit would occur next. Were it a planet the size of the Earth and the star as wide as the Sun, then the diameter and extinction ratios would be 1/100th and 1/10,000th respectively.

Whether small or large, we would expect that not all transits recorded would be a geometer's perfect diameter drawing, but more likely some sort of chord. It is remarkable that despite solar flares, sunspots and atmospheric turbulence a stellar signal variation of 1/10,000th once a planetary orbit can be detected at all by a space observatory.

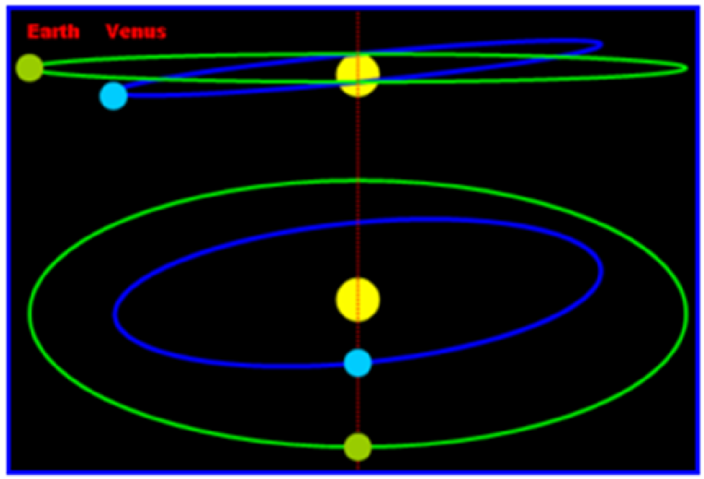

Figure 3. Orbital Planes of Earth & Venus Inclined 3 degrees, transit interval owing to time to repeated alignment at planar line of nodes. Image credit: Theresa Knott, public domain. Image source: Wikipedia.

History

Solar planetary transits were first observed long before the space age – but very infrequently. Since the Moon's "transit" (eclipse) blots out the sun's disk entirely due to the Moon's proximity to the terrestrial observer, the first instinct of many (including me) would be to dismiss this method as a means of detecting objects in deep space – and yet it works. To validate the heliocentric system, transits of Venus and Mercury (Figure 1) were essential in determining the Earth's distance from the Sun. The orbital plane of Venus is tilted 3 degrees from the plane of the ecliptic (Earth's orbital plane), enough to make its solar transit a relatively rare event (Figure 2).

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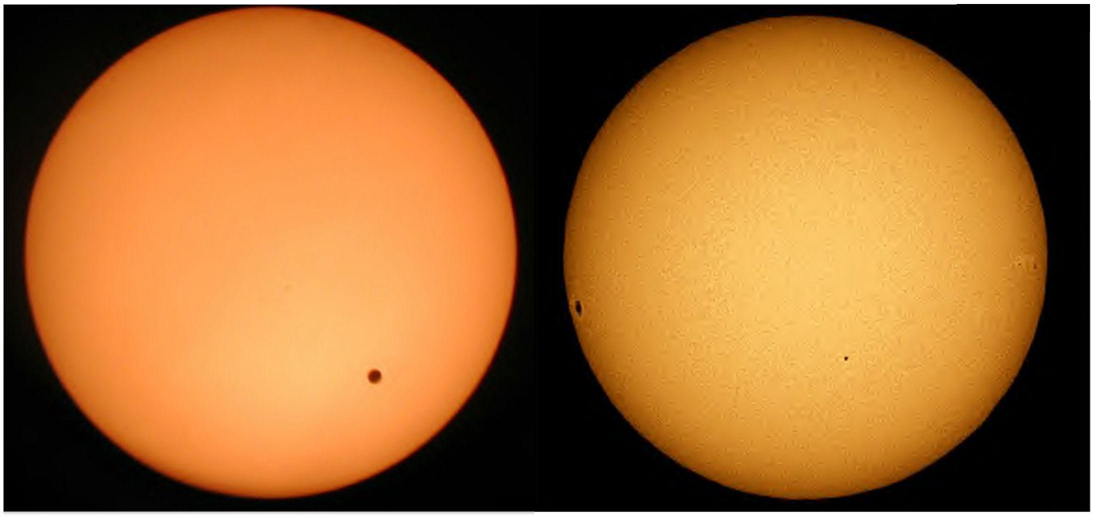

2004 Transit of star by earth-like planet: Venus. From Earth, Venus 1/3 distance to Sun giving it a 3x wider perceived radius. In image an absence of sunspots or flares, but evidence of limb darkening, considerations for Kepler mission.

Mercury transit November 8, 2006 with sun spots #921, 922, and 923. Mercury the small black in lower center. Sunspots at east and west equatorial edges.

Figure 1a&b Planetary Transits of Venus and Mercury viewed from Earth. Figure 1a: Image credit: see page 2. Figure 1b: Image credit: Mila Zinkova, public domain. Image source: Wikipedia.

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Transit predictions of Johannes Kepler's orbital calculations were confirmed by 17th century observations in France, England and elsewhere. The first recorded planetary solar transit was not Venus but Mercury by Jesuit priest and astronomer Pierre Gassendi in 1631 with Kepler's data in hand (Figure 3). He attempted to observe the transit of Venus in the same year, but in Paris it occurred at night. For centuries after Gassendi's missed opportunity, expeditions would subsequently launch all over the world to be in daylight for similar events: planetary transits, solar eclipses and occultations of stars by a planet or a moon.

Viewed from Earth, solar transits by the Moon, Venus and Mercury have different geometries. Full solar eclipse by the Moon is a remarkable geometric fit even though the Moon is but 1,740 kilometers in radius with the Sun at 700,000 kilometers – 400 times lunar radius. With Venus a third of the way to the Sun (orbital radius 0.67 AU), viewed from Earth, it is seen 3 times its size relative to the Sun in the photo. Mercury (orbital radius 0.39 AU) shown only as a dot in the adjacent photo, is still exaggerated by a factor of 1.64. These distortions disappear for interstellar observation.

Transits of Venus are among the rarest of predictable astronomical phenomena. They occur in a pattern that repeats every 243 years, with pairs of transits eight years apart separated by long gaps of 121.5 years and 105.5 years. Before 2004, the last pair of transits was in December 1874 and December 1882. The first of the 21st century pair of Venus transits took place on 8 June 2004; the next will be 6 June 2012. After 2012, plan for December 2117 and December 2125.

Had anyone imagined that we would someday watch for transits of planets orbiting distant stars? Gassendi's best known intellectual project attempted to reconcile Epicurean atomism with Christianity in the philosophical work Syntagma. As recently as 2011 a best-seller titled "Swerve" by Yale Professor Stephen Greenblatt reexamines the influence of the Epicurean writings of Lucretius on the Renaissance. In combination Democritus, Epicurus and the poet Lucretius provided arguments for a multiplicity or worlds now more than two millennia old. One would think that the concept of planets around other stars would result from a clear notion of stars being identified as suns stemming from pioneering work like Galileo's with telescopes, While Epicurean doctrine allowed for other worlds with life, their connection to other suns is left to conjecture. In 1591, before Galileo (1564-1642) discovered Jupiter's four largest "Galilean" moons in 1610, Giordano Bruno postulated, "planets revolving around other fixed stars, that is, suns." This was a bow to Copernican theory perhaps, but a mysterious inference when at their most intrepid his successors were preoccupied with our solar system. In fact, Johannes Kepler (1571-1630) wrote to Galileo relieved ("You have freed me from the great fear…"), since Galileo had discovered satellites around a planet of our solar system rather than in orbit about a star, not reintroducing issues related to Bruno's burning at the stake in 1600 for heresy.

In a 1992 NASA Solar System Exploration Division survey report titled "TOPS: Toward Other Planetary Systems" (a handy booklet I picked up at the Lunar and Planet Science Institute library one afternoon shortly after its publication), transit was mentioned as a possible means of "indirect planetary detection." In turn it cited a 1984 paper in the planetary science journal *Icarus* by coauthors W. J. Borucki and A. J. Summers. This was mentioned among the many avenues by which search for extra-solar planets might be pursued.

In the 1980s William Borucki working at NASA's Ames Research Center near Sunnyvale, CA had become involved with extra-solar planetary study groups, examining the problem with astronomical photometry, an instrumental approach of computing a star's overall luminosity. The TOPS report, besides supplying planetary formation theory discussed in the previous Horizons (pages 18-21, www.aiaa-houston.org, Nov. / Dec. 2011 issue), examined numerous detection approaches. Faint stars in binary systems had been detected for over a century by either astrometry of the visible star, or Doppler velocity determinations from absorption lines in the spectrum of

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visual components (the spectrum of the brighter star or of the unresolved combined light). Both methods were naturally enough expanded to searches for planets which were large enough to cause visible stars to revolve about system centers of mass.

The Doppler detection of planets is now well known, especially for its ability to detect very large planets close to their primaries. There is also much discussion about the difficulty of detecting Earth-like planets by the same technique – especially acquiring them visually. Astronomers and engineers are usually confronted with the issue of a habitable planet's relative faintness so near a Sun-like star – orders of magnitude fainter than the star – in the visible or infrared portions of the spectrum. Even with the best optics a star is difficult to resolve into a pinpoint. The halo surrounding stars in photographs is a harmonic aberration known as an Airy disk. Additionally, it was suspected that zodiacal dust in the solar system could obscure Earth from view by astronomers viewing from planets about other stars. If these stars had planets, would they not have zodiacal dust too?

The Transit Debate

Since planets are not bright compared to stars, could the approach to the problem be turned inside out? Could planets subtract sufficiently from stellar brightness to be detected? Could you distinguish an exoplanet from a sunspot (or a "star spot" in this case)? If Earth observers had to wait for 130-year intervals for Venus transit observations, what were the odds of detecting a transit at another star? Like waiting for a particular volcano to erupt? And how constant is the light of a star or even that of our Sun? Those who have worked with solar power might use the rule of thumb value of 1,370 watts per square meter for solar flux in vacuum at a distance of one Astronomical Unit (AU). But examining this "constant", how steady or accurate is it? Could it be 10 watts per square meter higher or lower in another reference book or six months ago? If so, is this because of short solar cycles or the Earth's slightly elliptical orbit? What was the sensitivity needed to detect a planet? We are aware of convective processes on our Sun's surface as well as flares from our Sun streaming far out in space. Stellar features are also obscured by turbulence. Would planetary transits share the same fate? And finally, could enough parallel sampling of stars be done to allow any odds for success in a spacecraft's mission lifetime?

Photos of the Mercury and Venus transits illustrate other problems. While the Venus image is clear, that of Mercury is dominated by sunspots. How the sunspots affect photometric measurements is not entirely clear, but perhaps stellar and planetary rotational rates can be discerned; otherwise a means of spectral filtering would be required. What's more, stars have "limb darkening." As seen from a distance they are brightest at their centers. For this issue, the plot of transits seems to show a transition to the star's center reaching a light intensity plateau.

These concerns explain why pursuit of photometric observation of planetary transits was viewed initially by many with skepticism. But while it is not easy to explain away all early concerns about the Kepler Observatory with this brief survey article, explanation for some stated concerns can be provided. In passing, we note it fortunate that Borucki's pro-photometric arguments prevailed. Otherwise space transit observing would have been left entirely to the European Space Agency project COROT. This was the first such (and less sensitive) space observatory to go on station, launched 27 December 2006, more than two years prior to the Kepler launch of March 2009. Although COROT made several large planet transit finds prior to Kepler, it was not the first to produce such discoveries. Some Doppler-discovered "super-Jupiters" were later observed transiting their stars, providing confirmation for the detection approach.

Just as with Doppler techniques, Jupiter-sized planets are more easily detected in transit than terrestrial planets in habitable zones, especially if the extra-solar Jupiters are located closer to their primaries than radii for habitability criteria allow (shorter period orbits and more frequent transits). If the Sun or a similar star's disk is uniformly luminous, then passage of a Jupiter or an Earth in front of it reduces the light by 1/100th or 1/10,000th respectively. To distinguish that an Earth sized object had transited in front of a star, however, it would require greater sensitivity than 1/10,000th or 100 parts per

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million (ppm). Kepler's sensitivity goal was set at 24 ppm and to date it has demonstrated 84 ppm. Do Doppler detected Jupiter-sized planets have moons? Kepler might eventually spot such bodies with secondary shallower preceding or trailing extinction dips. Target sensitivity might allow identification of Mars or Ganymede-sized bodies (Ganymede is a Galilean satellite of Jupiter.), but demonstrated capability illustrates how difficult this detection will be.

The likelihood of observing a transit depends on the size of the stellar disk and the distance between the planet and the star. Let us assume a star of the same mass and thermal flux as the Sun with planets similar to the Sun's aligned for transit in an observer's line of sight: an "Earth," a "Venus" and a "Jupiter." The 700,000-kilometer radius of the Sun (and this star) at one AU (150 million kilometers) results in a width of 0.5 degree or one chance in 180 to detect the "Earth" from another star in space via transit, based on possible inclination orientations from 0 to 90 degrees. It would take another two years to verify this with confirming passes. "Venus" at two thirds the distance would have a background disk a time and a half as wide (0.8 degree) and allow one chance in about 112. Perhaps some transit chords would be so far short of a diameter that they might not be useful enough for deriving planetary data; then the odds would have to be reduced accordingly. But Venus as viewed in transit from another star would be no more or less detectable than Earth save that it would be possible to confirm existence more quickly with its more frequent passage. Were Jupiter to pass in front of the Sun, it would extinguish more light, but at its further distance (5.2 AU), the viewing angle based on the Sun as a target would be about 0.1 degree; follow-ups would come nearly twelve years apart.

Using once again Earth and Sun based model, how long would a planetary transit last at a distance of one AU with a one-year period? Approximately the time to travel 1.4 million kilometers at thirty kilometers per second: less than 13 hours.

The Spacecraft as a Camera and Recorder

Kepler launched 07 March 2009 from Space Launch Complex 17-B Cape Canaveral Air Force Station Launch on board a Delta II (7925-10L) for a mission of at least 3.5 years of which nearly 3 have already elapsed. Positioned into an Earth-trailing heliocentric orbit with a 372.5 day period, its photometric instrumentation operates at bandwidth between 400 and 865 nanometers. Its diameter is 0.95 meters (3.1 feet) with a light collecting area 0.708 square meters.

The Kepler spacecraft, shown in Figure 4, has a mass of 1,039 kilograms (2,290 pounds in weight), a 0.95-meter (37.4 inch) aperture, and a 1.4-meter (55 inches) primary mirror – one of the largest mirrors on any telescope outside of Earth orbit.

The spacecraft has a 12-degree diameter field of view (FOV). Of this, 105-deg^2 is of science quality. The photometer provides soft rather than sharp focus for better photometry in the visual and near infrared range. The mission goal is a combined differential photometric precision of 20 ppm for visual magnitude m(V) =12 solar-like stars and 6.5-hour integration, though the observations so far fall short of this objective (see **Performance**).

An Earth-like transit produces a brightness change of 84 ppm and lasts for 13 hours when it crosses the center of the star. The focal plane of the spacecraft's camera is made up of 42 CCDs at 2,200 × 1,024 pixels, the largest camera launched into space with a resolution of 95 megapixels. The array is cooled by heat pipes connected to an external radiator. The CCDs are read out every six seconds (to limit saturation) and co-added on board for 30 minutes. At launch Kepler had the highest data rate of any NASA mission, the 30 minute sums of all 95 million pixels constitute more data than can be stored and sent back to Earth. So the science team pre-selected the relevant pixels associated with each star of interest, amounting to about 5% of the pixels. The data from these pixels are re-quantized, compressed and stored, along with other auxiliary data, in the on-board 16-gigabyte solid-state recorder.

Kepler's 115-deg^2 field of view (FOV) gives it a much higher probability of detecting Earth-like planets than

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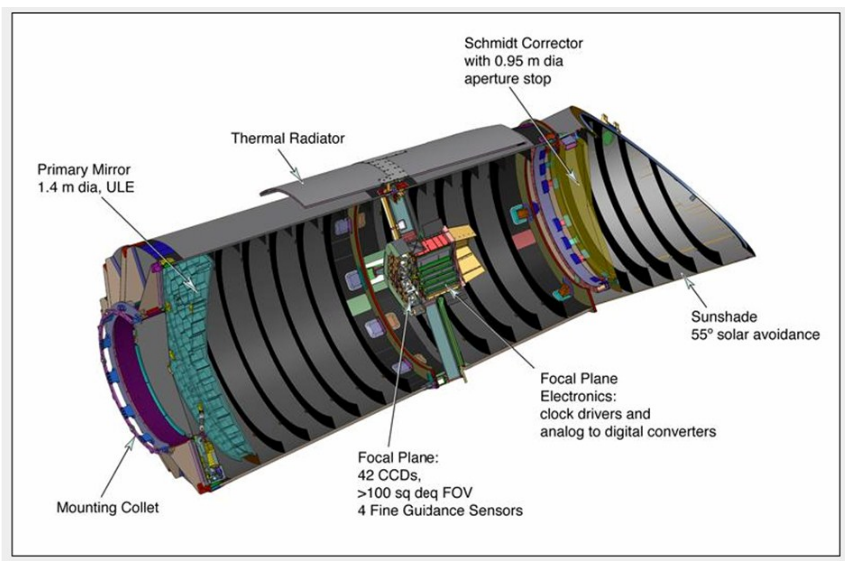
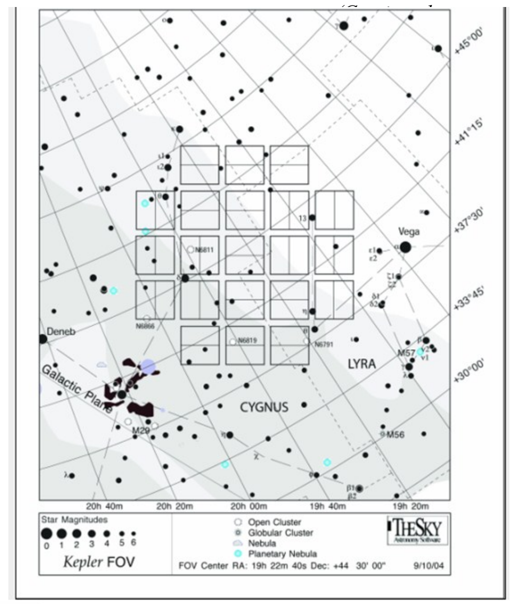
the Hubble Space Telescope or HST, (FOV ~ 10 deg^2). Moreover, Kepler is dedicated to detecting planetary transits, while the HST is used to address a wide range of scientific questions, and rarely looks continuously at just one star field. HST plus other space and ground observatories with smaller fields of view continue studies of objects such as Kepler-22b to derive orbital elements and features at other spectral bandwidths.

Performance

Kepler is working much better than any Earth-bound telescope, but still short of the design goals. The objective was a combined differential photometric precision (CDPP) of 20 ppm on a magnitude 12 star for a 6.5-hour integration. This estimate was developed allowing 10 ppm for stellar variability, roughly the value for the Sun. The obtained accuracy for this observation has a wide range, depending on the star and position on the focal plane, with a median of 29 ppm. Much additional noise indeed appears due to higher than expected stellar variability (19.5 ppm vs. the assumed 10 ppm) with the rest due to instrumental noise sources slightly larger than predicted. Work is ongoing to better understand, and perhaps calibrate out, instrument noise.

Since the signal from an Earth-sized planet is so close to the noise level (only 80 ppm), the increased noise means each individual transit is only a 2.7





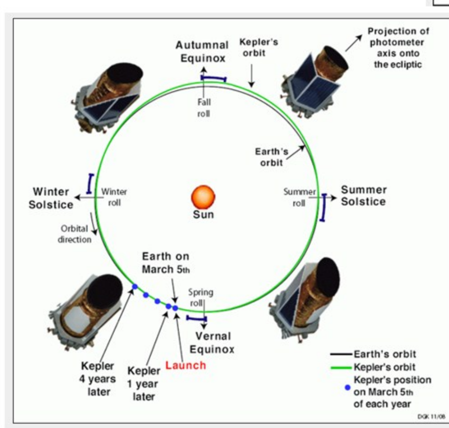


Figure 4 a, b, c & d Kepler Spacecraft Components, Position and Orientation in Space, Field of View (FOV). Image credit for FOV: Software Bisque. Image source: http://spacespin.org/article.php/90438-kepler-captures-first-views. Top left image credit: http://images.brighthub.com/eb/d/ebdbe7834492fb6aecea34aa6e54e16113d37e87_large.jpg. Figure 4c &d: http://kepler.nasa.gov.

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sigma event, instead of the intended 4 sigma. This, in turn, means more transits must be observed to be sure of a detection. Recent estimates indicate a 7-8 year mission, as opposed to the 3.5 years planned, would be needed to find all transiting Earth-sized planets. The spacecraft has enough fuel for such a mission, but there is no funding for it so far.

Of the approximately half-million stars in Kepler's field of view, around 150,000 stars were selected for observation, to be observed simultaneously, with the spacecraft measuring variations in their brightness every 30 minutes. This provides a better chance for seeing a transit. In addition, the 1-in-215 probability means that if 100% of stars observed had the same diameter as the Sun, and each had one Earth-like terrestrial planet in an orbit identical to that of the Earth, Kepler would find about 465; but if only 10% of stars observed were such, then it would find about 46. The mission is well suited to determine the frequency of Earth-like planets orbiting other stars.

Kepler Results

As the cover illustration collage indicates, Kepler results trend toward discovering planets with longer and longer periods. For an alien Kepler spacecraft looking for Earth transiting the Sun, three transits would require between two and three years. Kepler-22b is on the inner edge of a habitability zone of a star only slightly fainter (and less massive) than the Sun with a period of 290 days. Despite the earlier Doppler based results that presented a host of planets of Jupiter's mass or more, the Kepler candidate results for planets have thus far turned up many more Neptune-sized planets. More super-Earths are turning up than "Jupiters." Even Earth-sized candidates are about 40% as frequent as the Jupiters despite their near burial in background noise (Figure 5).

For purposes of presentation, Kepler investigators last December divided their results thus far into five principal planetary size classes: Earth, Super-Earth, Neptune-sized, Jupiter and Super-Jupiter size. Also the description of stars has been normalized in terms of surface temperature, leaving issues of mass, luminosity and radiative peak matters for audiences to mull later. When results for temperature in Figure 6 are compared with stellar classifications, it can be seen that lower-temperature stars are considerably less luminous than stars like the Sun. They cannot be seen over distances as great even though M stars are known to be more numerous than G-types. Lower temperature star radii fall off significantly as well. But even if stellar radii and surface areas were the same, according to black body radiation theory and Wien's law the spectral flux peak wavelength is inversely proportional to surface temperature. ($\lambda_{MAX} * T_{EFF}$ = constant). Given that the Sun's effective surface temperature is 5,780 degrees Kelvin and its peak emission wavelength is 501 nanometers or 5,010 angstroms, a sphere of the same size of half the temperature would emit at a peak wavelength 1,002 nanometers - slipping outside the range of Kepler visual to near infrared photometry (Figure 7). In some cases the distinction between Jupiter and larger planets is disregarded. The more massive planets do not vary much in diameter unless age and location with respect to their primary stars are taken into account.

Among the first 36 Kepler planetary confirmations, Kepler-22b stands out for its long period (289.9 days) vs. periods of less than one day (Kepler-10b) to 120 days in the first 21 systems, and temperatures are no lower than 400 degrees Kelvin – with one notable exception. Among these first 22 star systems are several multi-planet systems: one with 6 planets (Kepler-11); one with 5 (Kepler-20); two with 3 (Kepler-9 and 18) and two with 2 planets (Kepler-9 and 10). Kepler-20e possesses the smallest diameter (0.868 times Earth's radius) with Kepler-20f in second place with a radius slightly larger than Earth's (1.034 – see Figure 8), but the two planets possess effective temperatures of 1,040 and 705 degrees Kel-
(Continued on page 12)

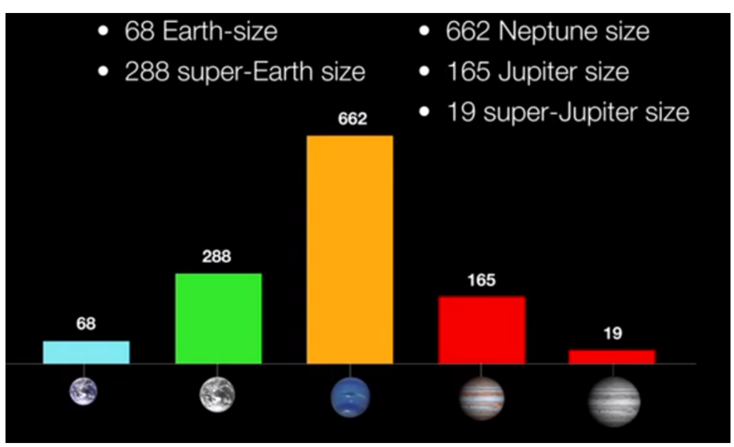


Figure 5: Number of planet candidates. Image credit: NASA.

Kepler-22b

(Continued from page 11)

vin respectively. The “notable exception” mentioned above is Kepler- 16b which orbits around tight, but relatively faint stellar binaries in 228 days with a temperature estimated between 170 and 200 degrees Kelvin (-154 to -100 Fahrenheit). The binaries eclipse and transit each other as well. The first three planets in the Kepler observatory numbering system were actually identified with ground telescopes and confirmed by the Kepler spacecraft as part of its in-flight calibration and test.

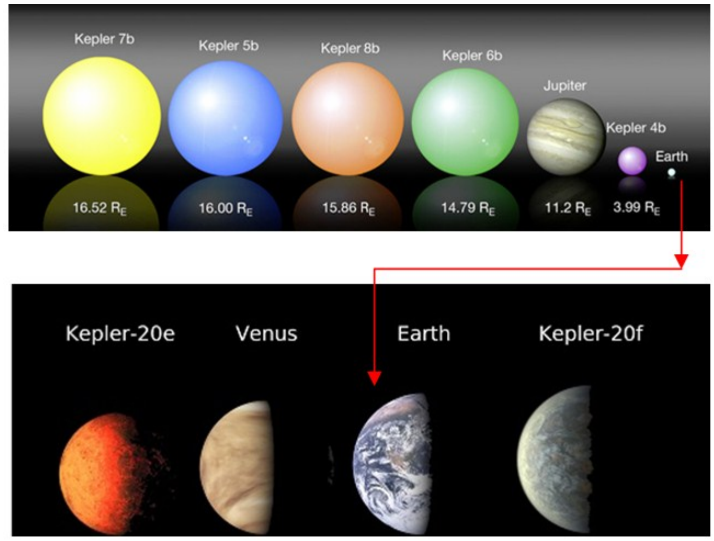
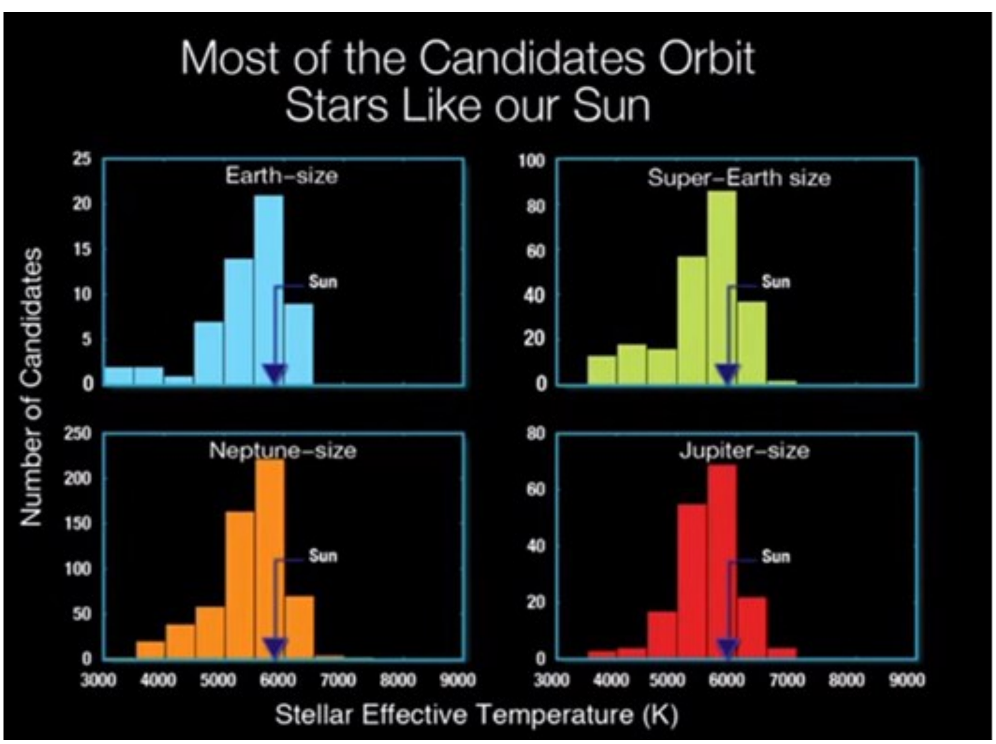


Figure 7: Planet Sizes Relative to Earth. Image credit: NASA.

During the January American Aeronautical Society conference in Austin, two more planets orbiting binary stars were added to the Kepler list (Kepler-34b and Kepler-35b), and stars identified with Kepler objects of interests (KOI) resulted in planet identifications by ground programs: two planets smaller but hotter than Earth and three planets closely orbiting a faint M-type dwarf similar to Barnard’s Star. Should the Kepler team follow the pattern of previous years, they might provide further updates in February.

The orbiting Spitzer Infrared Space Telescope has been the chief space observatory providing backup to the Kep-

(Continued on page 13)



Stellar Class	Radius R/R$_\odot$	Mass M/M$_\odot$	Luminosity L/L$_\odot$	Temperature K
O2	16	158	2,000,000	54,000
O5	14	58	800,000	46,000
B0	5.7	16	16,000	29,000
B5	3.7	5.4	750	15,200
A0	2.3	2.6	63	9,600
A5	1.8	1.9	24	8,700
F0	1.5	1.6	9.0	7,200
F5	1.2	1.35	4.0	6,400
G0	1.05	1.08	1.45	6,000
G2	1.0	1.0	1.0	5,700
G5	0.98	0.95	0.70	5,500
K0	0.89	0.83	0.36	5,150
K5	0.75	0.62	0.18	4,450
M0	0.64	0.47	0.075	3,850
M5	0.36	0.25	0.013	3,200
M8	0.15	0.10	0.0008	2,500
M9.5	0.10	0.08	0.0001	1,900

Figure 6: Beside Stellar Temperature, Planet Discoveries Affected by Stellar Numbers, Luminosity & Radius. Image credits: NASA.

Kepler-22b

(Continued from page 12)
ler Observatory. The Hubble Space Telescope (HST), though it has an aperture of 2.4 meters, had its photometer traded out for other instruments on the first space shuttle servicing flight and HST has limited infrared capability. But its successor, the James Webb Space Telescope has both wide aperture and highly sensitive infrared instrumentation. Besides looking at nearby stars for non-transiting planets, this yet-to-be-launched telescope might be able to detect planetary infrared atmospheric absorption bands (ozone, water vapor, methane), distinguishing Earth-like planets from exoplanets better described as lifeless rocks or bottomless wells of gas. The Kepler team continues work on its 3.5-year mission, finding what fraction of stars in our galaxy are hosts for Earth-like planets in habitable zones. And there is some chance that the mission can be extended to as long as eight years with the benefits of identifying exoplanets of longer and longer periods. In the meantime, with closer study, Kepler-22b could reveal itself to be a super-Earth or a diminutive, warm Neptune. But based on perceived discovery trends, Kepler-22b could very well be called Harbinger.

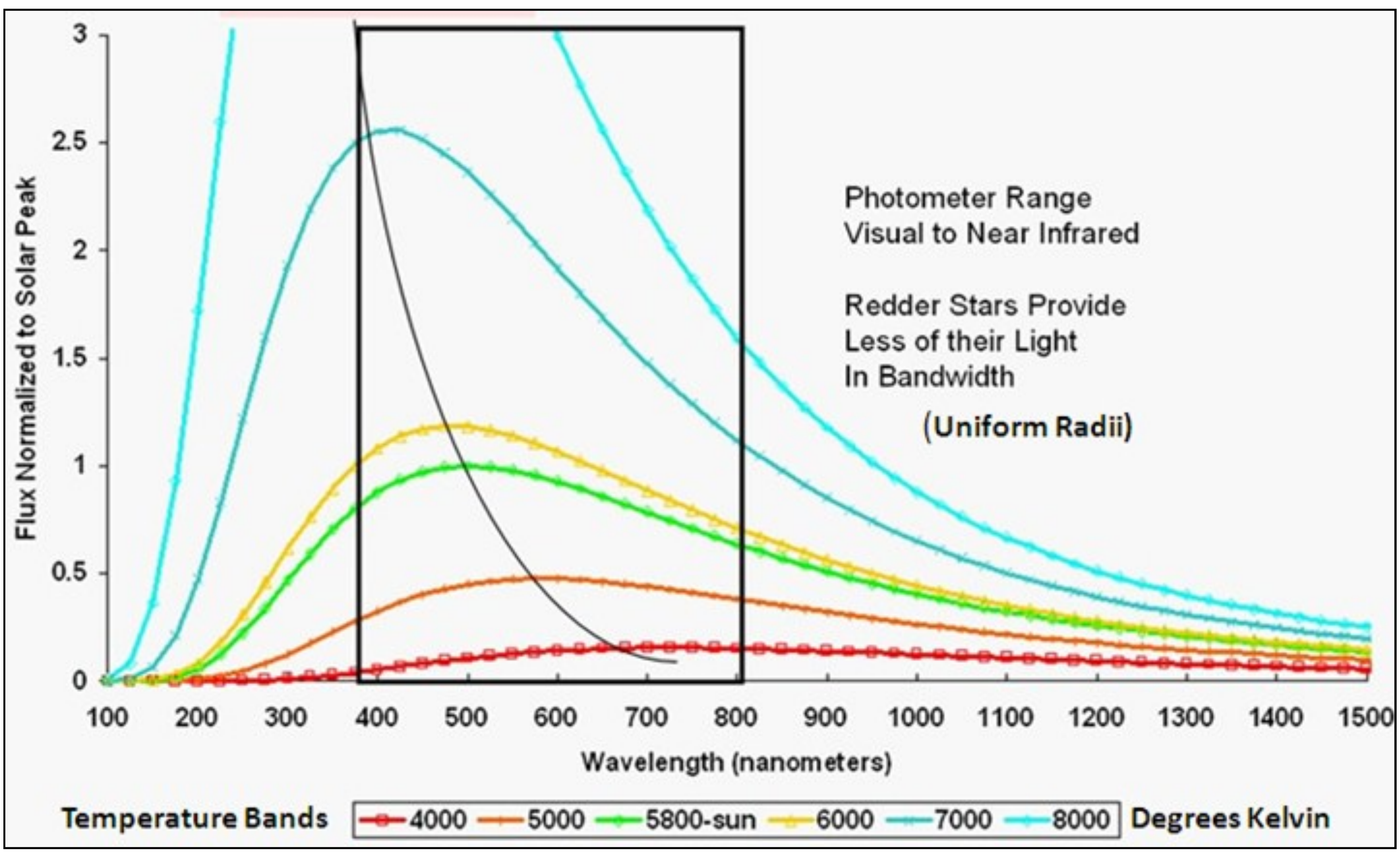


Figure 8: Flux Normalized to Solar Peak vs. Wavelength. Image credit: Wes Kelly.

Cassini

A Peek at *Cassini* after Seven Years in Orbit

DANIEL R. ADAMO, ASTRODYNAMICS CONSULTANT

[1]The most highly inclined major moons of Saturn are Mimas (inclination of 1.572°) and Iapetus (inclination of 7.489°). *Cassini* generally orbits between these two moons, whose mean distances from Saturn are 185,540 km and 3,560,840 km, respectively. All orbit and trajectory data supplied in this article are obtained from Jet Propulsion Laboratory's (JPL's) *Horizons* ephemeris computation system (accessible at http://ssd.jpl.nasa.gov/?horizons).

After becoming humankind's first artificial satellite of Saturn on 1 July 2004, the *Cassini* orbiter shared headlines with its companion spacecraft *Huygens* until the latter reached the surface of Saturn's largest moon Titan on 14 January 2005. Since then, *Cassini* has continued to observe Saturn, its rings, its moons, and its magnetosphere. Mission status, together with a wealth of imagery and other discoveries enabled by these observations, can be accessed at http://saturn.jpl.nasa.gov/home/index.cfm.

Trajectory design strategy supporting *Cassini*'s tour of the Saturn system is driven by two astrodynamic precepts. First, node placement with respect to Saturn's equatorial plane is critical to orbiter survival and mission success. Both ring material and Saturn's retinue of major moons lie within a few degrees of this plane[1]. Consequently, the distances from Saturn at which *Cassini* crosses the equatorial plane must be chosen with care to avoid catastrophic collisions and to obtain close-up observations of major moons. Furthermore, one of the nodes must never stray very far from 1,221,870 km, the mean distance of Saturn's largest moon Titan from the planet's center. Only Titan has sufficient mass to provide gravity assists making *Cassini*'s tour possible with the orbiter's limited propulsive capability.

The second precept relating to *Cassini* tour strategy is the orbiter's inclination with respect to Saturn's equatorial plane. *Cassini*'s as-flown and planned inclination is plotted in Figure 1.

When *Cassini* inclination is nearly zero, encounters with moons other than Titan are practical. During close approaches to Enceladus, *Cassini* has determined this moon is continually spewing briny ice from its south polar region, as depicted in Figure 2.

From a perspective near Saturn's equator, major moons can undergo mutual transits per the Figure 3 *Cassini* image. These geometries are much more likely to arise at lower orbit inclinations. In addition to their aesthetic appeal, images of such transits contribute to improved accuracy associated with the moons' ephemerides.

(Continued on page 15)

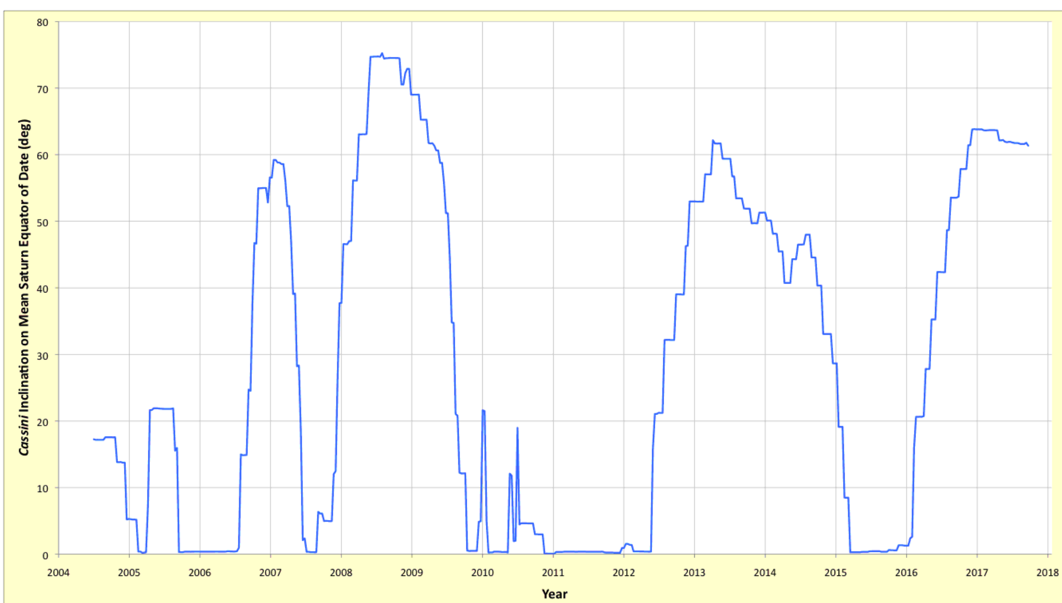
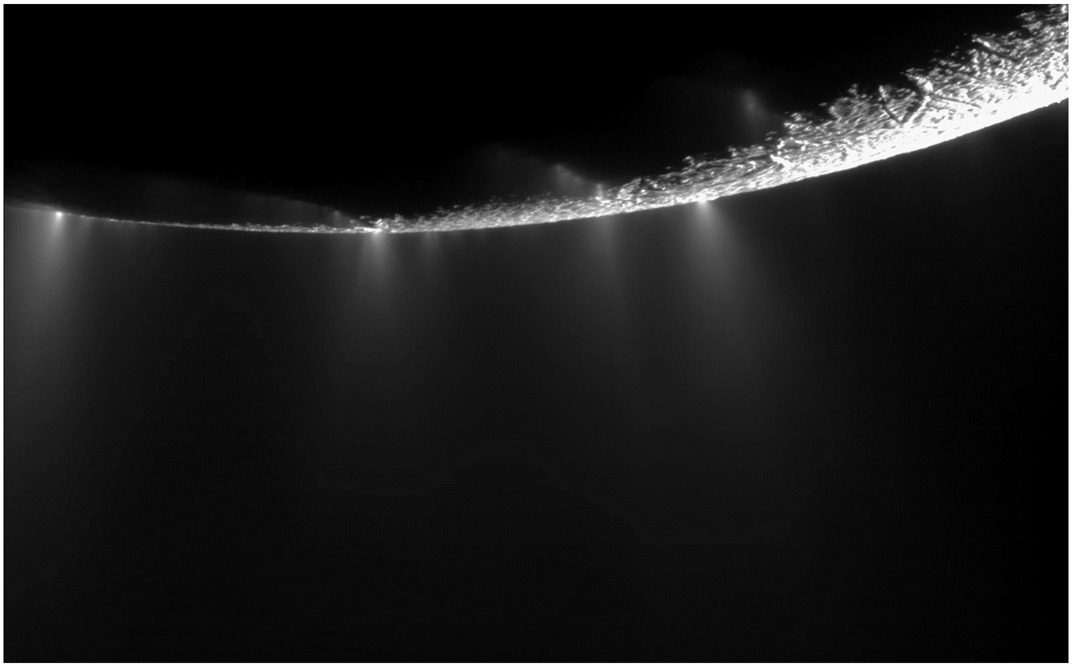


Figure 1. *Cassini* inclination with respect to Saturn's equatorial plane from Saturn orbit insertion in 2004 until planned mission termination in 2017. Each increment in inclination results from a Titan gravity assist.



Cassini

Figure 2. *Cassini* imaged briny ice plumes near the south pole of Saturn's moon Enceladus on 23 February 2010. Image PIA11688 credit NASA/JPL/ Space Science Institute (SSI).

(Continued from page 14)

The Figure 3 perspective near Saturn's equatorial plane provides a nearly edge-on and highly foreshortened view of the planet's rings. In contrast, Figure 4 is an example of perspective from well south of Saturn's equator. Observations of polar regions and most ring dynamics are therefore only practical with *Cassini*'s orbit at higher inclinations.

As the year 2011 draws to a close, Figure 1 indicates *Cassini* is about to end an extended period of low inclination observations. This orbit geometry enables a Dione encounter on 12 December, followed by a Titan encounter the next day, as illustrated in Figure 5. The Dione encounter is plotted relative to Dione in Figure 6, and the Titan encounter is plotted relative to Titan in Figure 7.

Figures 4, 5, 6 and 7 appear on the following two pages.

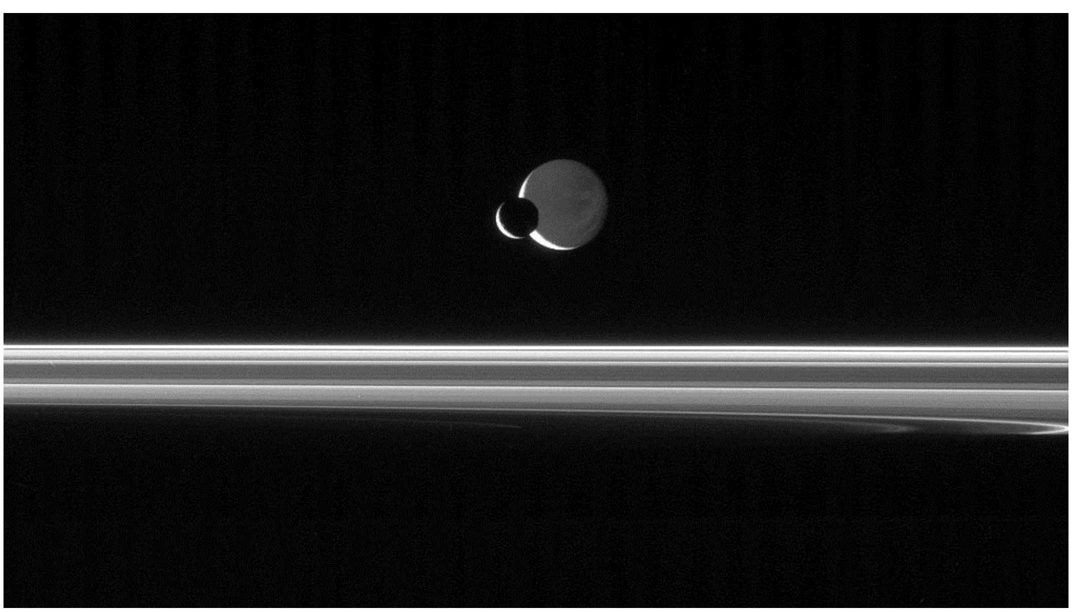


Figure 3. Mimas is seen transiting Dione from *Cassini* on 3 July 2006. Saturn's rings disappear into the planet's shadow at bottom. When this image was obtained, *Cassini* was located just "above" the rings' plane at 0.5° north latitude with respect to Saturn's equator. Because Mimas was located between *Cassini* and Saturn at this time, its nightside was only illuminated by starlight. In contrast, Dione was located across Saturn and its rings from *Cassini*, and its nightside was illuminated by reflected sunlight from the planet's dayside. Image PIA08228 credit NASA/JPL/ SSI.

Cassini

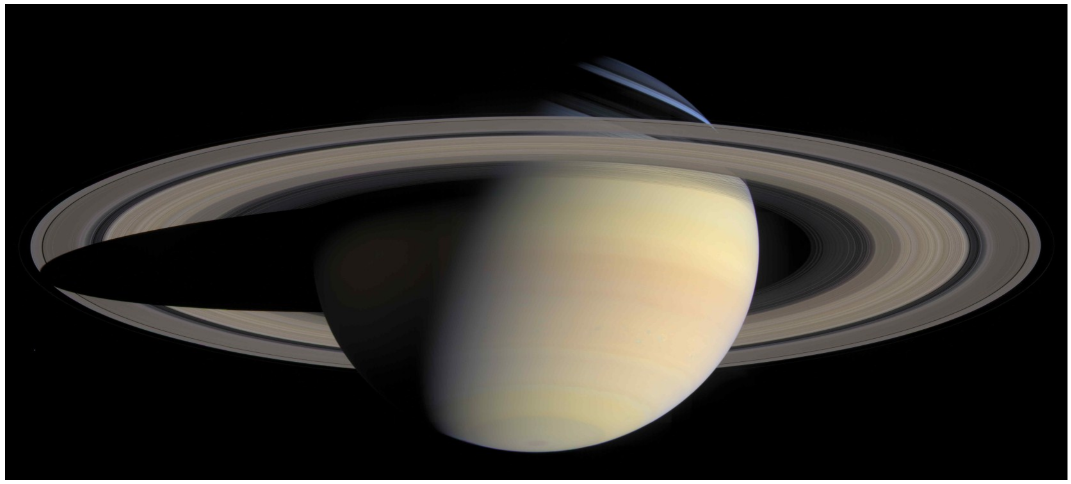


Figure 4. *Cassini* obtained this true color Saturn mosaic on 6 October 2004 from 18° south latitude. Note Saturn's shadow on the rings, the rings' shadow on Saturn, and the blue tint in Saturn's atmosphere at high northern latitudes during local winter. These are features difficult or impossible to view from Earth. Image PIA06193 credit NASA/JPL/SSI.

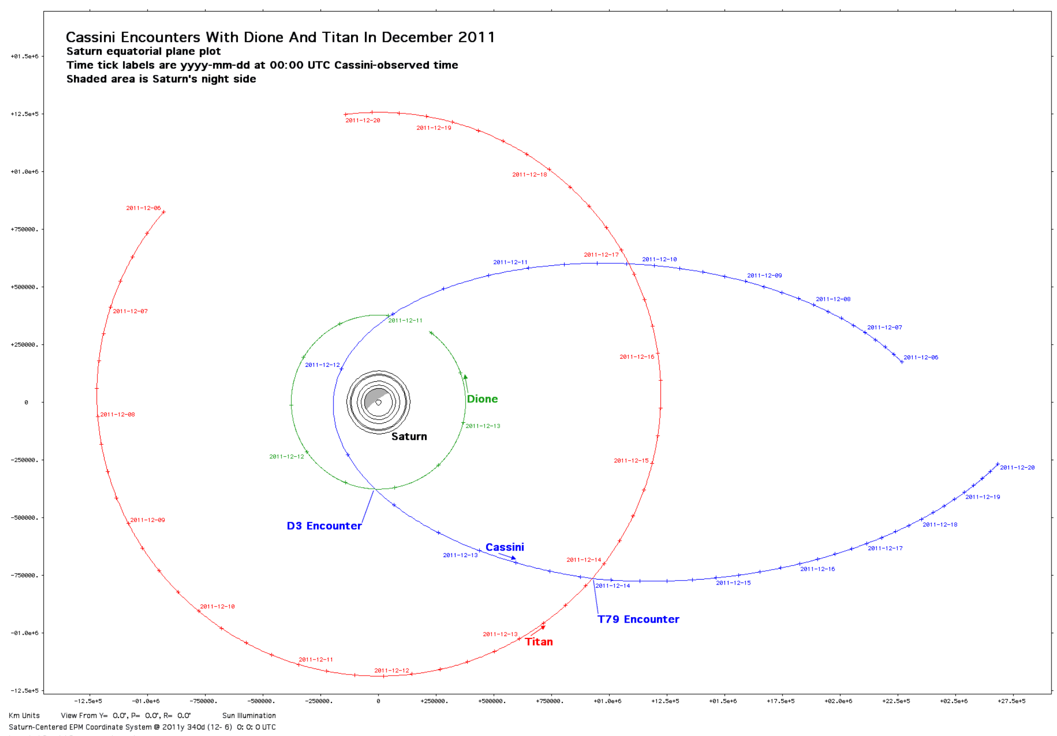


Figure 5. Mid-December 2011 *Cassini* encounters with moons Dione and Titan are plotted with respect to Saturn in the planet's equatorial plane. Although the Dione encounter has little effect on *Cassini's* orbit, the Titan encounter noticeably raises apochrone (*Cassini's* maximum distance from Saturn). Image credit: Daniel R. Adamo.

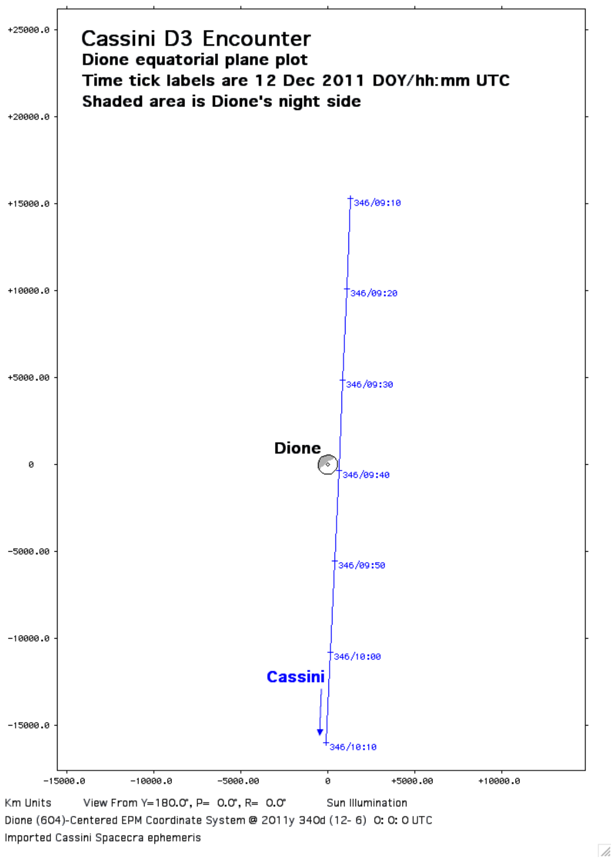


Figure 6. The "D3" Dione encounter is plotted relative to Dione in that moon's equatorial plane (parallel to that of Saturn) in nearly the same inertial orientation as Figure 5. *Cassini's* trajectory is indistinguishable from a straight line, indicating Dione exerts very little gravity perturbation, even with *Cassini's* periapsis height targeted at only 99 km. Image credit: Daniel R. Adamo.

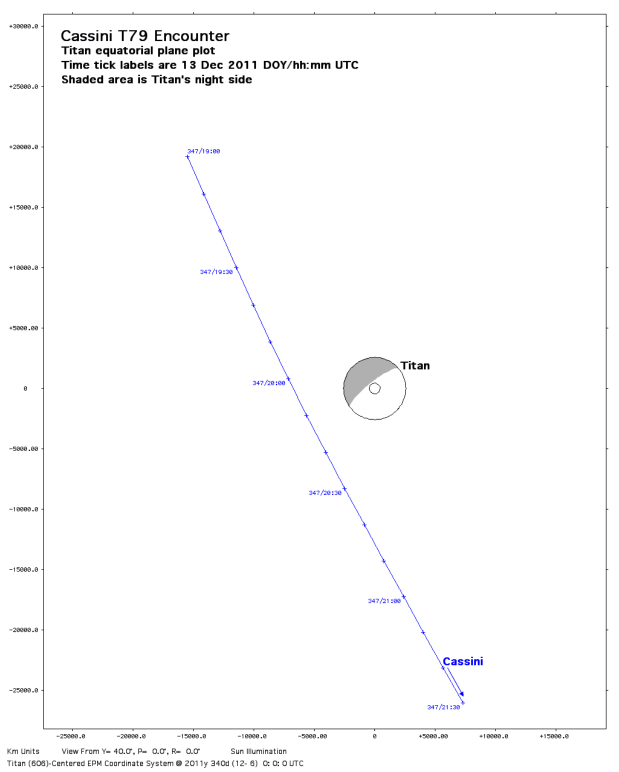


Figure 7. The "T79" Titan encounter is plotted relative to Titan in that moon's equatorial plane (parallel to that of Saturn) in nearly the same inertial orientation as Figure 5. Because *Cassini* periapsis is over the trailing hemisphere of Titan in its Saturn orbit, angular momentum is transferred from the moon to the orbiter, increasing its apochrone. This transfer is evident as a small deviation in *Cassini's* heading in the direction toward Titan, resulting in greater speed with respect to Saturn immediately after the encounter than immediately before it. Since Titan periapsis falls very near Titan's equator, low inclination with respect to Saturn's equator is preserved throughout the Titan encounter. Image credit: Daniel R. Adamo.

Dinner Meeting

Sustainable Use of Space Through Orbital Debris Control by Nicholas L. Johnson, NASA

Douglas Yazell, Editor

A grateful crowd enjoyed this dinner meeting presentation at NASA/JSC Gilruth Center on November 29, 2011.

Journalist Mark Carreau published an article in an aerospace periodical within a few days after this event. AIAA members can obtain details about that article via AIAA Daily Launch, a daily email news summary. That email note was sent to subscribing AIAA members not long after this event. At the bottom of each of those email notes is an "archive" link, so AIAA members can follow that link to find more about Mr. Carreau's article. As I write this article, I am "not allowed" access to that archive, perhaps due to recent AIAA web site updates ("under construction"). I recorded the audio on my iPad in case readers would like to use those files: editor-in-chief[at]aiaa-houston.org.

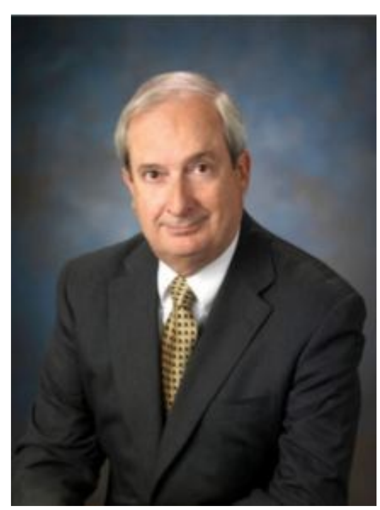
For this short article, the following details are presented from the publicity flyer:

Nicholas L. Johnson is Chief Scientist for Orbital Debris at NASA/JSC. As the agency authority on orbital debris, he is responsible for defining the debris environment, present and future, and for designing operational techniques by which crewed and robotic spacecraft may protect themselves from orbital debris, as well as minimize future growth of the orbital debris environment. Mr. Johnson also serves and the head of the U.S. delegation to the Inter-Agency Space Debris Coordination, and as the U.S. expert on orbital debris to the United Nations.

Prior to his joining NASA, Mr. Johnson served as advisory scientist for Teledyne Brown Engineering, Inc., and principal scientist for Kaman Sciences Corporation. At both companies, he supported a wide variety of U.S. government space endeavors. Mr. Johnson has served as a noncommissioned officer in the U.S. Air Force and as an officer in the U.S. Navy. He is the recipient of several military awards, including the Air Force Commendation Medal.

Mr. Johnson is a Distinguished Alumnus from the University of Memphis. He is a member of the International Academy of Astronautics and an Associate Fellow of AIAA. Mr. Johnson is internationally recognized as an authority on orbital debris and foreign space systems. He has authored eighteen books and more than 200 papers on these topics.

Right: Nicholas L. Johnson, NASA Chief Scientist for Orbital Debris, NASA/JSC. Image credit: AIAA publicity flyer.



1940 Air Terminal Museum at Hobby Airport An AIAA Historic Aerospace Site

Douglas Yazell, Editor

Wings & Wheels attracted a small but enthusiastic crowd on Saturday, December 17, 2011. One of the main attractions of this month's event was plane spotting, and interested visitors were driven around the airport runways with photography in mind. The related web site is:

www.houstonspotters.net

The author Mary Coleman-Woolslayer was a visitor this at this month's Wings & Wheels, with her excellent children's book, A Biplane and His Boy.

The Hartzell propeller above in two photographs highlights a black and white museum photograph, as well as the old brick walls that will be hidden one day soon as more building restoration is completed. (Image credits: D. Yazell.)

Muse Air was a non-smoking airline I appreciated early in my career, but some of my coworkers found it very difficult to endure non-smoking flights. When we returned to work in Downey, California, they smoked at their desks and everywhere in the workplace, a practice that continued until sometime around 1988 to 1992. TranStar Airlines, a part of Southwest Airlines, took over Muse Air and continued the non-smoking tradition. The TranStar jet image is from a postcard at the museum. (Image credits: D. Yazell.)

Keep an eye on the museum's web site to see what is coming up in 2012, especially with the monthly Wings & Wheels lunchtime programs on the third Saturday of most months (March 17, 2012, and April 21, 2012).

Until next issue, Happy Landings!

See www.tigermothpublications.com for more information about A Biplane and Her Boy.

Museum

Above: The museum in August of 2010. Image credit: Douglas Yazell

1940 Air Terminal Museum
8325 Travelair Street
Houston, Texas 77061
(713) 454-1940
www.1940airterminal.org

A bimonthly column about the museum.

Left: A framed poster at the museum. Image credit: Douglas Yazell.

Left: From 8 to 80 years of age, readers will like this book. It is aimed at the younger end of that age range, and it is beautifully illustrated. Image credit: A postcard used for book publicity.

New SPACE

SPACE: *Scientific Prepartory Academy for Cosmic Explorers.*

Isle of Man - An Excellent Space for Space

SHEN GE, CONTRIBUTOR

Nestled between the islands of Ireland and Great Britain floating on the frequently cold and stormy Irish Sea lies a verdant isle known as the Isle of Man. Known in its native Manx Gaelic language as "Ellan Vannin" where "ellan" means island in Gaelic, the island has been continuously inhabited since before 6500 BC. Never incorporated into the Roman Empire or later Great Britain, its status as a self-governing state continues today.

At first glance, an island with a population less than 90,000 people and an area less than 230 square miles may seem the most unlikely place for aerospace development. Indeed, according to South African expat and aerospace consultant Carla Sharpe, currently living on the Isle of Man, there are only about 30 people on the island actively involved in the space industry.

Yet, the Isle of Man was named the fifth most likely nation to next reach the moon in 2010. In October of 2010, it played host to the Google Lunar X Prize and became an annual sponsor of the X Prize. The Google Lunar X Prize contestant Odyssey Moon was established on the island. In January 2011, two research space stations owned by the new space company Excalibur Almaz arrived on the island and were kept at an aircraft hangar at the airfield at the former Jurby Royal Air Force base located near the northern parish of Jurby, in a town with less than 700 residents.

This flourishing energy is due to a combination of pre-existing favorable economic conditions and strong government support. The Isle of Man has long been recognized as a global finance center. In recent years, the attention has expanded to include more tangible industries, notably aerospace. The Isle of Man government created the Office of Space Commerce via the Department of Economic Development headed by Tim Craine to facilitate the support and collaboration between the local government and any international space entrepreneur willing to establish a presence there.

My December 2011 trip with my business partner Virgiliu (Virgil) Pop, a space lawyer from Romania, to the Isle of Man was as pleasant as predicted by the promotional materials on the Isle of Man website *www.spaceisle.com.* The pleasant stay was also predicted in correspondence with Christopher Stott, an Isle of Man native and a space entrepreneur who currently lives in Houston with his astronaut wife Nicole Stott. Virgil and I were on the Isle of Man for a week to scout potential venues for our summer 2012 space conference and to obtain government and industry support for our company called the Scientific Preparatory Academy for Cosmic Explorers (SPACE) to be established there.

Despite a shaky start with half a day of delayed flights due to persistent storms, we managed to eventually land on the Isle of Man in one piece. Our local legal contact Ranulf

Below: Coastline on a December dawn. Image credit: Shen Ge.

Lucas provided us with a light afternoon lunch before we all dashed off to the government office. The first person we met was Tim Craine, a modest man who showed genuine passion for space. Despite his busy schedule, he spent an hour in person with us in his government office's meeting room and answered all our questions in a patient and straightforward manner. When we discussed our need for government support for our venture, he was quick to state that he can provide an assistant to overlook our business plan as soon as we can send him one. On a quirky note, he seems to have a fascination with China given that he has more than 20 Chinese ties and was wearing one decorated with Chinese writing when we met with him.

At the same meeting sat Me-Shell Berry, an energetic lady originally from Houston who migrated to the Isle of Man 14 years ago and decided to stay permanently with a family. She is now an event organizer for the Department of Education. She is also in charge of the Conrad Foundation on the Isle of Man, an international inventor's challenge for high school students. Through the Department of Education, she provided the buses and personnel for the 2011 Excalibur Almaz opening exhibition presenting their planned space stations.

The next few days passed by with talks at various locations throughout Douglas with local entrepreneurs. At the International Institute of Space Commerce (IISC), we sat down with Chris Hall, an entrepreneur who formerly worked for Manx Telecom, and Ian Jarrett, the CFO of Mansat LLC. Mr. Hall was respectful and curious while Mr. Jarrett was eager to help. We met Kurt Roosen, an entrepreneur who had aspirations similar to ours, though his interest was in IT instead of space. He has founded the Manx Education Foundation (MEF), an organization dedicated to creating the first IT university on the Isle of Man, with its location at the decaying, ancient Castle Mona, which will be renovated by September 2012.

The last government official we met was the acting Attorney General who allocated several hours to sit down with us and go through our company's articles of association and by-laws. She pointed out flaws and answered all of our questions.

The last few days concluded with tours of possible conference venues on the island. The seaside views were spectacular and we will select a venue with that scenery in mind. These included the five-star Sefton Hotel, the government conference venue Villa Marina, the Claremont Hotel, the Nunnery, and the Manx Museum. The Nunnery, despite its limited indoor seating, attracted us immediately as an apt location for a dinner social thanks to its verdant outdoor space.

At the Manx Museum, we coincidentally met an older amateur astronomer who worked at there. His enthusiasm was infectious, and he led us to the countryside where he helped build the local astronomy society's observatory. Despite the rainy dreary weather, typical of the Isle of Man in winter, we found that the observatory itself was well-stocked and warm. The cloudy sky didn't dull our sunny spirits as we settled down, chatting about the observatory and space in general.

In conclusion, the Isle of Man is proving to be an excellent space for space. Our trip was a resounding success and we are happy to inform you that our space conference is happening on the Isle of Man on July 9-10, 2012 at the Sefton Hotel. You can register using this web site:

http://spaceconf.com/

A bit of advice: Don't visit the Isle of Man in December if you can avoid it, since Mother Nature will offer you a cold reception. Thankfully, the local citizens will always offer you a warm welcome. The SPACE conference in July 2012 will assuredly receive a warm reception from both the Mother Nature and the residents of the Isle of Man.

New SPACE

SPACE: Scientific Prepartory Academy for Cosmic Explorers.

Below: Nunnery grounds on a December afternoon. Image credit: Shen Ge.

3AF MP

Biodiversity and Light Pollution

PHILIPPE MAIRET AND JEAN-LUC CHANEL, 3AF MP

3AF MP:
l'Association Aeronautique et Astronautique de France, Midi-Pyrenees chapter, www.3af-mp.fr.
Our French sister section is 3AF MP. See our web page at www.aiaa-houston.org. Click on technical committees, International Space Activities Committee (ISAC). The ISAC is chaired by Ludmila Dmitriev-Odier. An update to the 3AF MP organization chart is on page 27 of our last issue.

In 2010, declared "International Year of Biodiversity" by the United Nations, international commitments and actions were taken in Nagoya (Japan) to stem the loss of biodiversity in the world. This is a real *challenge* to consider, one that is essential to life on Earth, like national and international policies concerning global warming, and one that if not addressed, would generate a cost equivalent to 7% of global Gross Domestic Product (GDP) by 2050.

In France, the Ministry of Ecology presented, on Thursday, May 19, 2011, its plan to halt biodiversity loss in recent years. This effort must be integrated into all public policies in all sectors: water, soil, climate, energy, agriculture, forestry, urban planning... It would also be prudent to experiment with business units and management of collaborative fishing. This year the French government plans to launch the worksite "Creation of a national map of natural and semi-natural habitats, with a planned completion date of 2018."

Overseas, in French-administered territories outside of the European continent (Outre-Mer in French) "regions that host 3,500 plant species and 400 vertebrate animals unique to the world," the French government "conducts a survey of plant species harvested for traditional use." It will "open a specific service to mobilize patronage in favor of biodiversity."

In this struggle for biodiversity, let us not forget to fight also, simultaneously, against light pollution due in particular to the sometimes excessive nighttime lighting of cities. This type of pollution may interfere, on the one hand, with observations of the night sky dear to astronomers, whether amateur, semi-professional and professional, and, on the other hand, harm biodiversity by degrading the capability of certain animal and plant species to protect against the excess of light. Not to mention that some humans may also be affected by too much light at night.

With regard to animal species, the excessive nighttime brightness longer allows distinguishing day from night, and trips that take place usually at night can not be guaranteed. In addition, reproductive cycles are modified and unfortunately upset.

Articles about light pollution have been published recently in 3AF journals: la Gazette 3AF MP No. 16 (March-August 2009) and No. 18 (January-April 2010), and 3AF La Lettre (The Letter) No. 8 (October 2009). Presentations on the subject took place in the recent past in Fleurance, France in the Gers region in 2009 (as part of the International Year of Astronomy), in Pibrac, France in Haute-Garonne region in 2010, at La Geode in Paris, France in 2010, and during the event "Ciel en Fête" (http://cielenfete.fr/ , the second occurrence of this event in 2011 in Toulouse, France).

What could be the "uphill paths" to fight against light pollution?

- Reduce energy costs while ensuring the safety of persons and property. Some studies, including road safety studies, show a maximum lighting of the road is not a guarantee to better "identify" the other vehicle, in that it is normally illuminated by its own light. Moreover, studies show no correlation between brightness of such maximum lighting and frequency of collisions. However, a minimum illumination is essential to walk normally. It is also a psychological consideration.

Below: rana-palustris-5.jpg. Image credit: http://www.grenouilles.free.fr/especes/grenouille_marais.php

• Think twice before setting up outdoor lighting, whether public or commercial. (ANPCEN proposes solutions. It is up to AFE to consider them and bring together an “ad hoc” working group.)

Editor’s note: ANPCEN: www.anpcen.fr: Association Nationale pour la Protection du Ciel et de l'Environnement Nocturnes, National Association for the Protection of heaven and the night environment. AFE: www.afe-eclairage.com.fr: Association Française de l'Eclairage, French Association of Lighting

• Organize awareness campaigns.

All this takes time, resources and means.

Recently, there has been discussion of "corridors" or "reserves" of dark sky. In the Midi-Pyrenees region of France, let us note the existence of the "Black Triangle du Quercy" and the proposed first RICE ("International Dark Sky Reserve") in Europe that would be created around the Pic du Midi (supported by the association PIRENE).

RICE was awarded for the first time in the world in Quebec, Canada in the Parc du Mont-Mégantic, by the International Dark Sky Association (IDSA).

For a related story, let us recall, "Night Lighting and Light Pollution", filed as part of a public consultation for the revision of the Master Plan of the City of Montreal, Quebec.

This document (www.faaq.org/menucielnoir/memoire_ville_montreal.pdf), prepared by Chloé Legris, at the time a trainee engineer in charge of the project ASTRO-Lab of Mont-Mégantic, was presented by the Federation of Amateur Astronomers of Quebec. This public consultation allowed creation of a real awareness on the part of local government.

According to the French magazine "Sky and Space" (Ciel et Espace) of December 2011, park officials of Mount Mégantic were "coming back to the frontline of the war" to promote or enforce the regulations: for example, Mount Mégantic "defends its heavenly heritage."

If keeping the label "RICE" can be a challenge, it is worth noting that local initiatives in France allow cities (of about 5,000 inhabitants) and villages to obtain the label of "Celestial City" or "Village Etoile" *(Editor’s note: Village with a Starry Night Sky : http://www.villes-et-villages-etoiles.fr)*, since the event "The Day of the Night" was recently created, and in 1992 the United Nations Educational, Scientific and Cultural Organization (UNESCO) declared the night sky to be the worldwide heritage of mankind.

It is not unthinkable that in the future it will be possible to observe (or measure) light pollution with space assets, other than the International Space Station (ISS) and DMSP satellites, and compare the results with observations and measurements from the ground.

Editor’s note (Wikipedia): The Defense Meteorological Satellite Program (DMSP) monitors meteorological, oceanographic, and solar-terrestrial physics for the United States Department of Defense.

Below: Poppies. Image credit: Public domain, Franz Eugen Köhler, Köhler's Medizinal-Pflanzen. Image source: Wikipedia (http://fr.wikipedia.org).

3AF MP

The Right Stuff at the Cinémathèque de Toulouse

PHILIPPE MAIRET, 3AF MP

3AF MP: l'Association Aeronautique et Astronautique de France, Midi-Pyrenees chapter, www.3af-mp.fr. Our French sister section is 3AF MP. See our web page at www.aiaa-houston.org. Click on technical committees, International Space Activities Committee (ISAC). The ISAC is chaired by Ludmila Dmitriev-Odier. An update to the 3AF MP organization chart is on page 27 of our last issue.

Wednesday, November 30, 2011, moviegoers rediscovered, or discovered, perhaps, the movie masterpiece The Right Stuff by director Philip Kaufman, dedicated to early American spaceflight. First released to theaters in 1983, this 3-hour and 15-minute epic centered on the Mercury program brought to life the difficult conquest of the "new frontier" with intensity, emotion, and even poetry, against a background of competing with the Soviets.

The Toulouse Film Archive gave moviegoers the go for launch Wednesday, November 30, 2011, at 7:30 PM for a special session in the presence of Philippe Perrin, astronaut and test pilot.

It should be noted that this film screening introduces a series entitled "The Space Odyssey" in partnership with the Centre Nationale d'Etudes Spatiales (CNES) and the Cité de l'Espace in which several space-themed films will be programmed at the Cinémathèque de Toulouse, but also at the Cité de l'Espace, until a date not yet specified in May 2012.

Price: 6.50 €
Concessions: € 5.50
Youth under 18: € 3

(Tickets are available at the Cinémathèque and the Cité de l'Espace.)

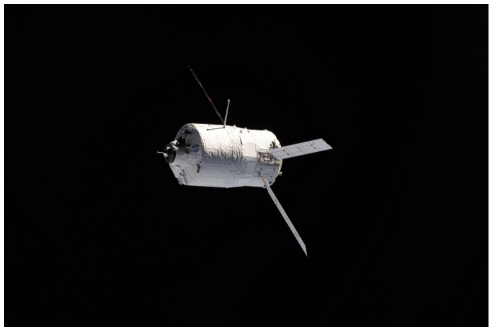
To find the film series program for The Space Odyssey:

http://www.lacinemathequedetoulouse.com/

www.cite-espace.com

Right: The film festival web site provided a preview of the movie, The Right Stuff. Image credit: www.enjoyspace.com.

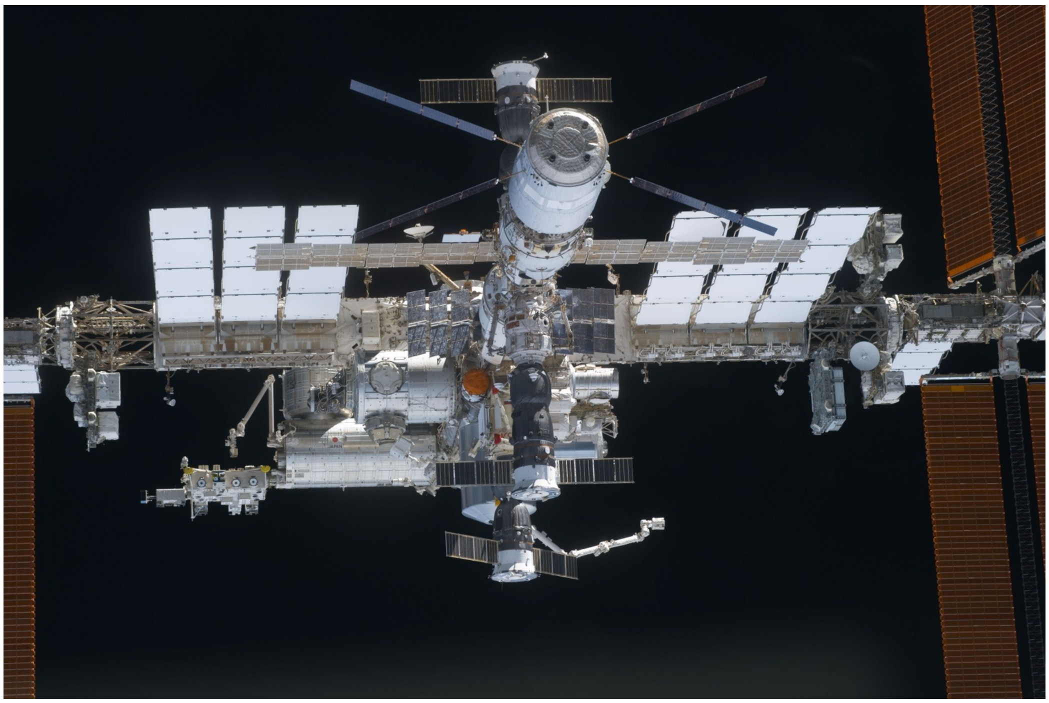
Right: Film festival information for the event in Toulouse, France, November 2011 through a date to be determined in May 2012. Image credit: La Cité de l'Espace.



3AF MP

Far Left: ATV-2 patch. Image credit: ESA (http://esamultimedia.esa.int/images/atv/ATV2_LOGO_Hi-res.jpg)

Left: ATV-2 approaching ISS. Image credit: ESA (http://www.esa.int/images/5475346310_db1a344f8a_o.jpg)



A close-up view of the International Space Station is featured in this image photographed by an STS-133 crew member on space shuttle Discovery after the station and shuttle began their post-undocking relative separation. Undocking of the two spacecraft occurred at 7 a.m. (EST) on March 7, 2011. Discovery spent eight days, 16 hours, and 46 minutes attached to the orbiting laboratory. Image credit: NASA. Image source: http://spaceflight.nasa.gov/gallery/images/shuttle/sts-133/html/s133e011051.html.

Left: A view of ATV-2 *Johannes Kepler* as seen from the International Space Station during its launch aboard an Ariane 5 ES-ATV launch vehicle on 16 February 2011. The Expedition 26 crew member aboard the International Space Station who snapped this photograph of the Ariane 5 rocket, barely visible in the far background, just after lift off from Europe's Spaceport in Kourou, French Guiana, and the rest of the crew have a special interest in the occurrence. ESA's second Automated Transfer Vehicle, Johannes Kepler, was just a short time earlier (21:50 GMT or 18:50 Kourou time on Feb. 16, 2011) launched toward its low orbit destination and eventual link-up with the ISS. The unmanned supply ship is planned to deliver critical supplies and reboost the space station during its almost four-month mission. The elbow of Canadarm2 is in the foreground. Paolo Nespoli, Photographer, Astronaut, 16 February 2011, 517837main_iss026e027223_full.jpg. Image credit: NASA. Image source: http://cio.gsfc.nasa.gov/images/content/

Lunch-n-Learn

Warp Drives: A Curious History

DR. ALBERT A. JACKSON IV

Dr. Albert A. Jackson is Chair of the AIAA Houston Section astrodynamics technical committee, a Fellow of the British Interplanetary Society, an AIAA Associate Fellow, and a visiting scientist at the Lunar and Planetary Institute in Houston, Texas.

Dr. Jackson organized and hosted this event with guest speaker Dr. Harold "Sonny" White, NASA/JSC.

Technical committee web pages: www.aiaa-houston.org.

In 1966 I went to the World Science Fiction convention in Cleveland (the 24th). Gene Roddenberry showed the pilot for *Star Trek*, not used, later fixed up as a two episode entry.

All the SF fans there were enthusiastic about it. Later Gene was in a hallway of the hotel with a model of the Enterprise, kind of an "author's tour", except, alas, he was alone, no one was talking to him. I went up to him and said, "Gee, I sure recognize an almost complete nomenclature from prose science fiction presented in your teleplay."

He said, "You should, I was and am an avid reader of modern science fiction prose." A few years later I don't think I could have approached him through a crowd of admirers.

Maybe one of the first super-science terminologies a viewer of *Star Trek* remembers is "Warp Factor," as applied to the faster-than-light "warp drive."

Warp Drive has to be one of the oddest histories as a "super-science" artifact of modern prose science fiction. The great fathers of modern science fiction (SF), Jules Vern and, especially, H.G. Wells did not concern themselves with flight out of the solar system.

The infusion of spaceflight into modern SF prose occurred early. The basic physics known by Verne and Wells was transformed by Konstantin Tsiolkovsky, Hermann Oberth and Robert H. Goddard into solid engineering physics. This was picked up by writers to become an emerging prose entertainment known as science fiction, SF. (One notes that SF, even early on, was more than space flight.)

From the 1920s, and especially in the 1930s, there was a general exploration of the solar system by spaceship. Soon the Solar System became too small a stage and the stars beckoned. It is quite remarkable that SF writers showed a comprehensive grasp of what interstellar distances meant. Maybe more remarkable was an understanding the implications of Special Relativity and light as a speed limit, though E. E. Smith's early *Skylark* and later *Lensman* stories show a joyous disregard for any such natural speed limits.

Interstellar distances could be bridged with slower than light technology. Konstantin Tsiolkovsky first saw this using generation starships. This was extended to "World Ships" by the brilliant British physicist John Desmond Bernal's 1929 work *The World, the Flesh and the Devil.*

It was John W. Campbell, with a degree in physics from Duke University, who laid the

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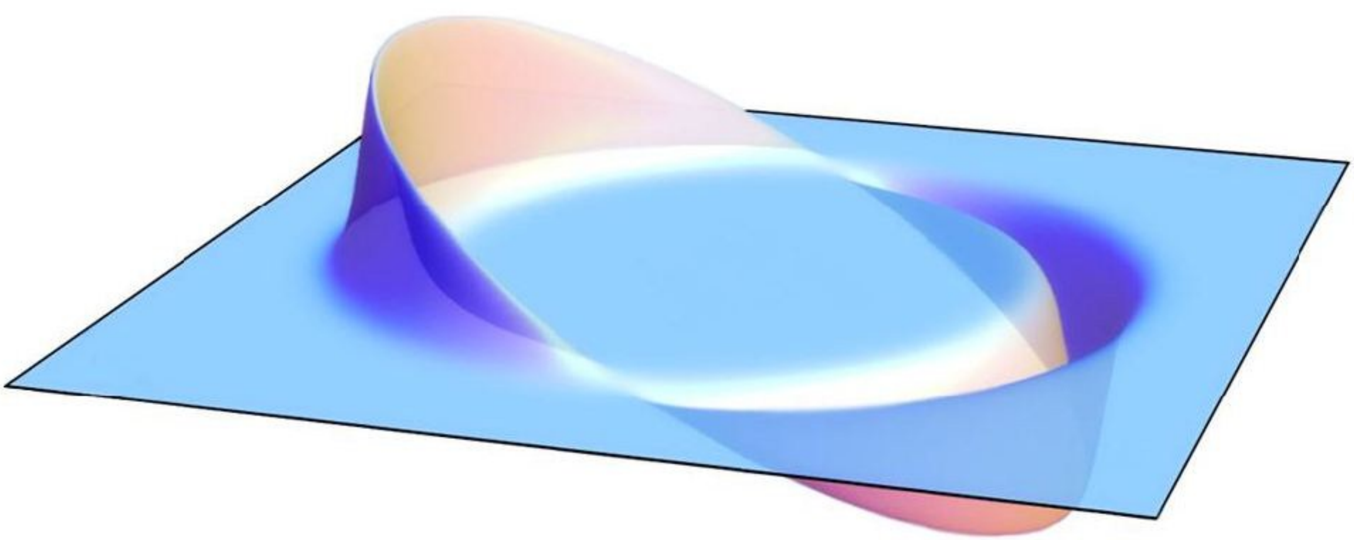
Below: A graphic image from our publicity flyer for this event. See the figure on the next page for details. Image credit: Dr. Harold "Sonny" White, NASA/JSC.



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groundwork for faster than light (FTL) technology using essentially extrapolated curved space time from Einstein's General theory of Relativity (GR) in his stories *Islands of Space* (1931) and *The Mightiest Machine* (1934). I don't think GR is ever explicit in SF FTL in the 1930's and 1940's but it shadows almost every story that uses "warp" drives, hyper-drives, jump-drives… the list is almost endless. By the 1930s, science fiction writers were feeling confined by the solar system. A greater stage, the Galaxy, beckoned, and it was remarkable that most of the writers with no scientific background knew not only about stellar distances but Special Relativity. Light as a limiting speed was a plot annoyance, even though writers continued to extract great stories from slower-than-light travel.

After John Campbell became editor of *Astounding Science Fiction* magazine in 1938, a greater degree of sophistication in narrative was introduced. Campbell was fond of a method of narrative exposition that eschewed "technobabble", preferring a "just do it" approach to achieve a higher level of verisimilitude.

One of the most influential stories from 1940 to 1950 was Isaac Asimov's *Foundation Series*. The "hyper-drive" was used as a standard plot device to fix up the problems with keeping timelines running in parallel. Another space-time concept was to use multiply connected topology.

In 1935 Einstein and Rosen revised an idea by Herman Weyl of using a singularity-free version of the Schwarzschild solution of the GR equation which they called a "bridge." They were not inter-

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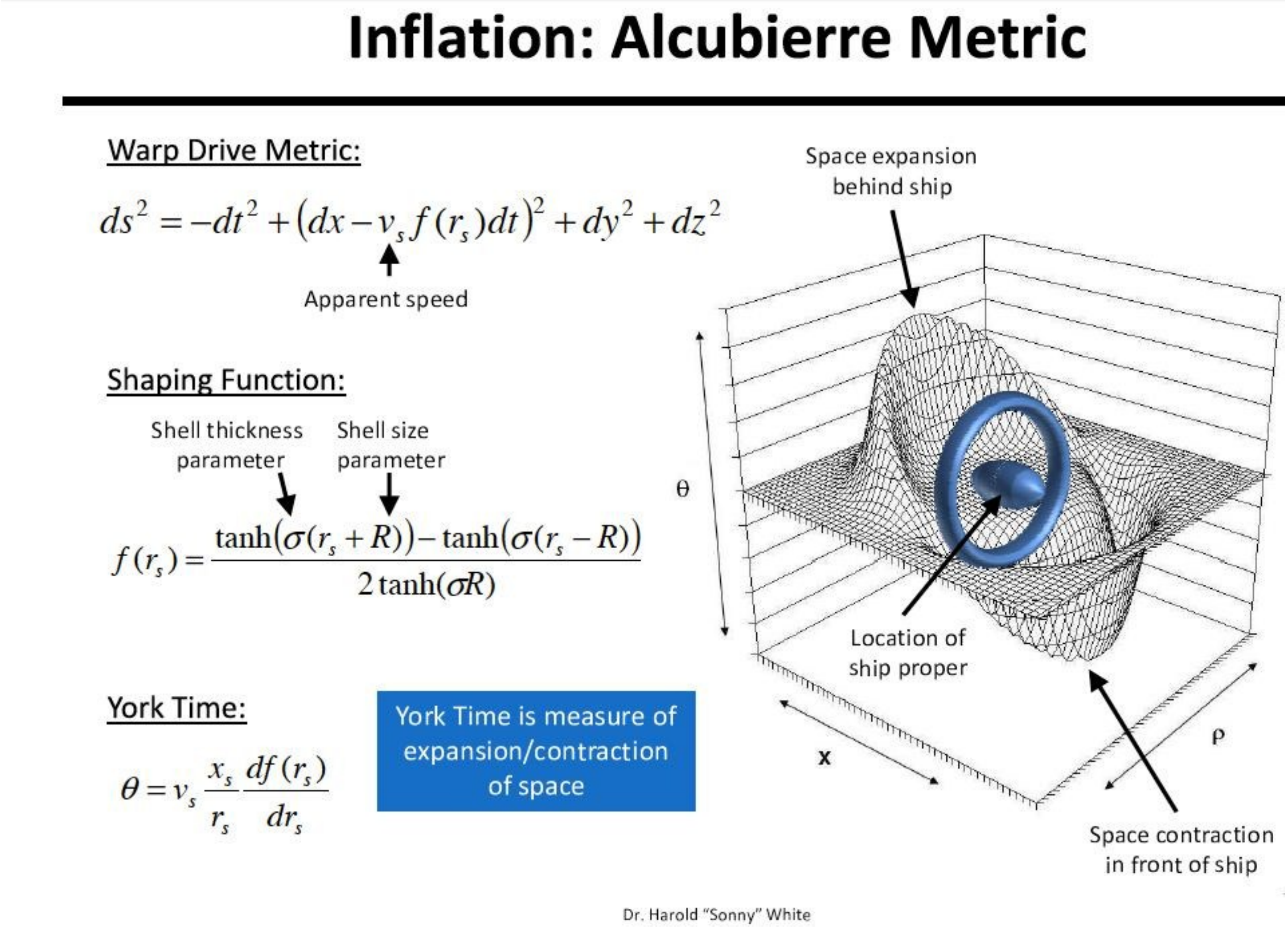
Below: A chart from the presentation. Image credit: Dr. Harold "Sonny" White, NASA/JSC.



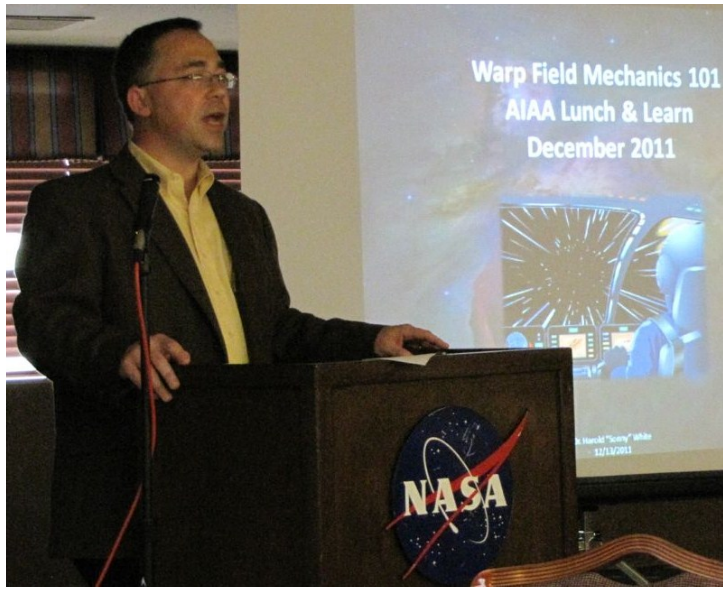
Lunch-n-Learn

(Continued from page 27)

ested in it as a mode of transport, but wanted to thread it with an electric field and build a model electron. Somehow , by way of someone who knew the paper, this passed into the culture of SF writers. A terrific description of 'jumps through hyperspace' is given by Robert Heinlein in his 1953 novel *Starman Jones.*

The use of FTL in SF stretches from the late 1920's to the present. Its use was a curious motivator. There was no real physical basis for it in the non-fictional world. The revival of Black Hole physics (first studied in the 1930s) in the 1960s had inspired SF writers to use them as space-time shortcuts until it became it was shown that was a good way to get killed!

Then, when writing the novel *Contact*, Carl Sagan Sagan asked Kip Thorne, the Feynman Professor of Physics at Caltech, for advice to help ensure that the method chosen to transport the novel's heroine across the Galaxy would not be scientifically ludicrous. Thorne suggested replacing



the notion of diving through a black hole as a portal to distant realms with the idea of using a wormhole. Thorne suggested that Sagan use a wormhole in his novel, rather than a black hole. However, if wormholes are to be used for FTL communication or transportation, the issue of stability is an extremely important one. In 1962, Wheeler and Fuller demonstrated that Einstein-Rosen wormholes are extremely unstable, so that if such a wormhole should happen to appear spontaneously it would pinch off so rapidly that not even one photon of light could pass through it before it closed. Kip Thorne and his graduate students at Caltech turned the problem around and asked what forms of matter are required to hold a wormhole open permanently, so no pinch-off occurs? The answer is 'exotic' matter, a highly stressed matter, with enormous tensile strengths.

On December 13, 2011, the AIAA Houston Section Astrodynamics Technical Committee had Dr. Harold "Sonny" White of NASA/JSC present his work

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From the publicity flyer:
Warp Field Mechanics 101
"The goal of timely interstellar flight – to reach other habitable worlds within a human lifespan – cannot be achieved with even the most refined technological applications of accrued physics. The exhaust velocity and propellant mass required when applying the rocket equation, or the power level required for photon momentum transfer, are so high as to fall into the realm of the seemingly impossible. To circumvent these limits, it is desired that new, advantageous, propulsion physics awaits discovery. For example, if it were possible to move a spacecraft using the interactions between the craft and its surrounding space without needing propellant (a space drive), then the energy requirements would drop from exponential to squared functions of trip velocity. If faster-than-light travel becomes possible, then the light years spanning star systems become traversable within a human lifespan." - Marc Mills - Tau Zero Foundation.

Editor's note: Attendance was 65 or 70 people for this popular event in the Lone Star room at NASA/JSC Gilruth Center. Most of the charts from the presentation are available here: http://ntrs.nasa.gov/archive/nasa/casi.ntrs.nasa.gov/20110015936_2011016932.pdf. Related information: http://ntrs.nasa.gov/archive/nasa/casi.ntrs.nasa.gov/20110023492_2011024705.pdf.

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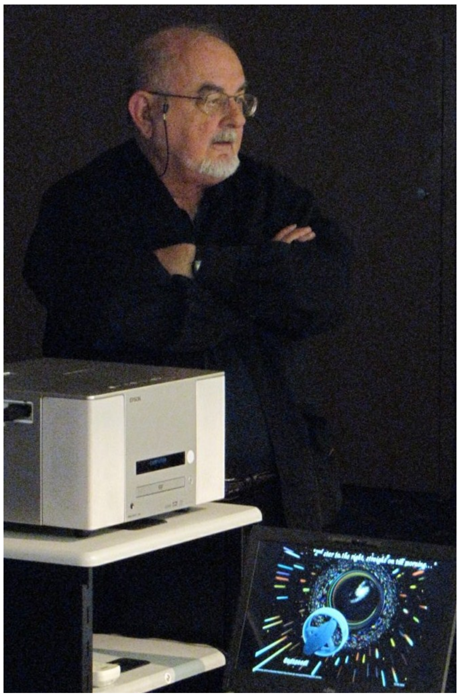
on a warp drive. After its invention as a plot device in SF in the early 1930's through Star Trek an unexpected theoretical development was presented in the early 1990's. In 1994, Miquel Alcubierre, at the time a graduate student at the University of Wales in Cardiff, published a mathematical description of a spacetime geometry that embodies the properties usually associated in science fiction with a "warp drive." In this geometry, a "starship" can apparently travel faster than the speed of light, traversing interstellar distances of many light years in an arbitrarily short time – both as measured by those on the starship, and those at the destination. One says "apparently" because the starship never exceeds the speed of light as measured by a local observer - the basic tenet of Einstein's special relativity is not violated.



"Exotic matter" is matter that has properties not usually seen in ordinary situations - such as negative mass or energy densities. There is not room here to expand on the theory of wormhole or warp travel. The reader can find a recent exposition in the recent book *Time Travel and Warp Drives,* by Allen Everett and Thomas Roman, University of Chicago, December 2011.

It has been a long path from prose fiction to theoretical constructs of FTL travel. A lot of physics needs to be developed, such as an understanding of "exotic" matter and physics aspects of the solutions regarding their stability. Even if all this can be solved, the technological construction of warp dive starships will present an enormous engineering feat.

Lunch-n-Learn

Left: Dr. Albert A. Jackson IV. Image credit: Douglas Yazell.

Left: Dr. Harold "Sonny" White, NASA/JSC. Image credits: Douglas Yazell.

Astrodynamics

Phobos-Grunt's Inexorable Trans-Mars Injection Countdown Clock

DANIEL R. ADAMO, ASTRODYNAMICS CONSULTANT

Introduction

Phobos-Grunt, Russia's sample return mission targeting the martian moon Phobos, was to have marked this nation's return to interplanetary spaceflight after a decades-long hiatus. Launched from Baikonur Cosmodrome, Kazakhstan atop a *Zenit* rocket on 8 November 2011 at 20:16:03 UTC[1], *Phobos-Grunt* achieved a nominal Earth parking orbit with apogee/perigee heights of 344/204 km[2]. The initial Figure 1 ground track terminus is annotated "separation of the SC from the LV". This event occurred 11 min after launch and corresponds to *Phobos-Grunt* separation from the *Zenit* second stage.

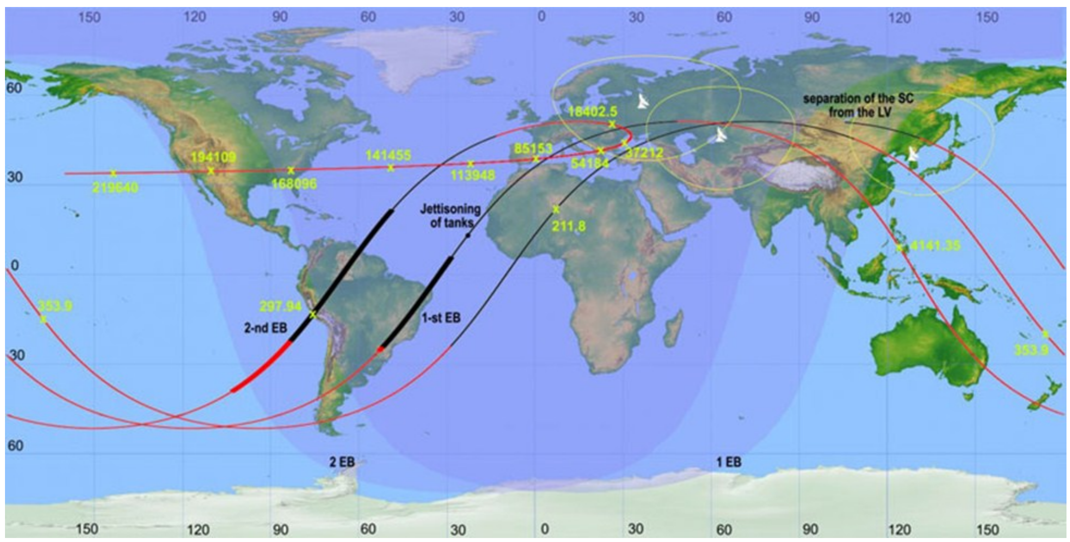


Figure 1. This world map illustrates *Phobos-Grunt*'s planned ground track from Earth parking orbit insertion through two trans-Mars injection (TMI) burns[3]. The track is colored red when the spacecraft is in sunlight and black when in Earth's shadow. Broader track segments over South America, labeled "1st EB" and "2nd EB", indicate the two TMI burn arcs. Shaded regions, indicating night on Earth's surface during each TMI burn, are labeled "1 EB" and "2 EB" near Antarctica. *Phobos-Grunt* height above Earth in km is annotated in yellow-green with "x" ground track markers. By the time *Phobos-Grunt*'s planned trajectory is over Texas post-TMI, the departing spacecraft was to have been about half the Moon's distance from Earth. Image credit: RussianSpaceWeb.com.

After separation from *Zenit*, *Phobos-Grunt* was to have performed a 2-burn TMI to depart Earth orbit and intercept Mars in September 2012. Both TMI burns, together with the initial Mars orbit insertion (MOI) burn, rely on a modified *Fregat*-MT upper stage known as *Flagman* for propulsion. *Flagman* uses hypergolic propellant and is equipped with drop tanks dedicated to the first TMI burn. After depletion, these tanks are to be left in Earth orbit after the first TMI burn has raised apogee to 4100 km. This event is marked by Figure 1's "Jettisoning of tanks" annotation off the West African coast.

Although telemetry was received from *Phobos-Grunt* as it passed over Russia an orbit after launch, no transmissions from the spacecraft were detected an orbit later. Tracking in this

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[1]This actual launch time and other as-flown events, together with all *Phobos-Grunt* mission planning and performance specifications cited in this article, are obtained from RussianSpaceWeb.com unless noted otherwise.

[2]These apsis heights are inferred from USSTRATCOM 2-line element set (TLE) #4 with epoch 9 November 2011 at 09:33:24 UTC.

[3]Throughout this article, a "burn" event refers to planned operation of *Phobos-Grunt* propulsion systems. This is distinct from an "impulse", which refers to an instantaneous approximation of how one or more burns would affect the *Phobos-Grunt* trajectory.

(Continued from page 30)
timeframe also confirmed the first TMI burn had not occurred. Some relatively minor propulsive events could be associated with *Phobos-Grunt* tracking in the interval from 10 to 20 November 2011, but nothing resembling the first TMI burn ever occurred. Meanwhile, limited telemetry was received from the spacecraft over Australia on 22 and 23 November 2011, but no capability to reliably command *Phobos-Grunt* was ever established after launch. The original parking orbit ultimately decayed on 15 January 2012.

This article will make no attempt to explain why *Phobos-Grunt* systems were unable to perform TMI. Rather, the intent here is to first estimate the change-in-velocity capability (Δv_C) of *Flagman*. With this Δv_C budget, nominal *Phobos-Grunt* launch season closure is estimated. Finally, the Earth parking orbit into which *Phobos-Grunt* actually launched is assessed to estimate the latest possible date on which the planned mission could be recovered. Whereas the launch season is reported to have closed on 20 November 2011, this season was largely irrelevant to mission recovery after 8 November's actual launch. Following this launch, a "no later than" TMI countdown clock was set to expire in only a few days as *Phobos-Grunt's* Earth parking orbit plane failed to remain adequately aligned with the required Earth departure asymptote bound for Mars.

Consequently, study of hypothetical *Phobos-Grunt* mission recovery scenarios is highly relevant to any interplanetary transportation architecture requiring a multi-launch campaign prepositioning mass in low Earth orbit (LEO) prior to its departure for an interplanetary destination. The first launch in such a campaign also initiates an Earth departure countdown clock that cannot be slipped later by more than a few days.

Estimated *Flagman* TMI/MOI Capability

Total *Flagman* change-in-velocity capability for *Phobos-Grunt* is defined as the sum of two components such that $\Delta v_C = \Delta v_1 + \Delta v_{23}$. The first component, Δv_1, is generated with propellant from *Flagman*'s drop tanks and applies exclusively to TMI's first burn. After drop tank jettison, Δv_{23} capability is applicable to both the second TMI burn and initial MOI. Throughout Δv_C estimation, a best-case simplifying assumption is made that all *Flagman* burns are applied impulsively to maximize Δv_C. This reinforces the "latest possible" pedigree associated with launch season closure and last possible mission recovery estimates presented subsequently.

Data relevant to Δv_C estimation are as follows.

$m_{i1} \equiv$ total spacecraft mass at *Zenit* separation and at first TMI burn ignition = 13,500 kg
$m_{s1} \equiv$ depleted *Flagman* drop tanks mass at jettison = 335 kg
$m_{p1} \equiv$ usable propellant mass in *Flagman* drop tanks = 3050 kg
$m_{p23} \equiv$ usable propellant mass in *Flagman* (not including m_{p1}) = 7050 kg
$I_{SP} \equiv$ *Flagman* hypergolic propulsion specific impulse = 333.2 s
$g \equiv$ gravitational acceleration at Earth's surface = 0.00980665 km/s^2
$v_X \equiv$ *Flagman* hypergolic propulsion exhaust speed = $g\ I_{SP}$ = 3.268 km/s

The rocket equation then determines both Δv_C components.

$$\Delta v_1 = v_X \,\mathrm{Ln}\{m_{i1} / (m_{i1} - m_{p1})\} = 0.837 \text{ km/s}$$
$$\Delta v_{23} = v_X \,\mathrm{Ln}\{(m_{i1} - m_{p1} - m_{s1}) / (m_{i1} - m_{p1} - m_{s1} - m_{p23})\} = 3.902 \text{ km/s}$$

Summing these components produces Δv_C = 4.739 km/s.

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Astrodynamics

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Estimated *Phobos-Grunt* Launch Season Closure Date

It is essential to recognize the total change-in-velocity requirement Δv_R associated with any *Phobos-Grunt* launch season date assumes no launch has taken place until that date. This requirement is the sum of two components such that $\Delta v_R = \Delta v_{TMI} + \Delta v_{MOI}$. Because these components are assumed to be instantaneous, the first is computed as a single impulse even though TMI is planned with 2 burns. Since launch on a previous date has not imposed any geometric Earth departure constraints, Δv_{TMI} is assumed perfectly posigrade. Likewise, Δv_{MOI} is assumed perfectly retrograde, rendering Δv_R free of all radial and planar steering losses.

A heliocentric elliptic transfer arc connecting Earth and Mars is fundamental to computing Δv_R. Heliocentric velocities at the termini of this arc are byproducts of a corresponding Lambert boundary value problem solution[4]. Earth-centered speed at the arc's departure terminus is $v_{\infty D}$, and Mars-centered speed at the arc's arrival terminus is $v_{\infty A}$.

[4]Additional *Phobos-Grunt* mission planning information, together with a little experimentation, reveal the launch season of interest utilizes Type II (long-way) Lambert boundary conditions with heliocentric transfer arcs between 180° and 360°.

At TMI, *Phobos-Grunt* is assumed to be moving in a circular orbit of height H_{TMI} = 274 km. This value is the average of apsis heights previously given for *Phobos-Grunt*'s actual Earth parking orbit on 8 November 2011 at 20:16:03 UTC. With the following data[5],

[5]Physical values for the Earth and Mars provided in this article are obtained from the Jet Propulsion Laboratory's *Horizons* on-line solar system data and ephemeris computation service at http://ssd.jpl.nasa.gov/?horizons.

$\mu_E \equiv$ Earth's reduced mass = 398,600.44 km^3/s^2
$R_E \equiv$ Earth's radius = 6378.136 km
$r_{TMI} = R_E + H_{TMI}$ = 6652.136 km

patched conic theory leads to an expression for Δv_{TMI}.

$$\Delta v_{TMI} = \sqrt{\frac{2\mu_E}{r_{TMI}} + v_{\infty D}^2} - \sqrt{\frac{\mu_E}{r_{TMI}}}$$

Following initial MOI, *Phobos-Grunt* mission planning calls for the spacecraft to be at periapsis of a Mars-centered elliptic orbit whose apsis heights are H_A = 80,000 km and H_{MOI} = 800 km. With the following data,

$\mu_M \equiv$ Mars's reduced mass = 42,828.3 km^3/s^2
$R_M \equiv$ Mars's radius = 3394 km
$r_{MOI} = R_M + H_{MOI}$ = 4194 km
$a_{MOI} = R_M + (H_A + H_{MOI}) / 2$ = 43,794 km

patched conic theory leads to an expression for Δv_{MOI}.

$$\Delta v_{MOI} = \sqrt{\frac{2\mu_M}{r_{MOI}} + v_{\infty A}^2} - \sqrt{\mu_M\left(\frac{2}{r_{MOI}} - \frac{1}{a_{MOI}}\right)}$$

In practice, a set of Lambert solutions is generated for each launch/TMI/departure date in the *Phobos-Grunt* season, beginning with 9 November 2011. While solutions in a set share the same Earth departure date and other Lambert boundary conditions, each Mars arrival date is unique. The solution whose Mars arrival date results in the smallest Δv_R for the set is assessed to determine whether or not the minimal Δv_R is less than Δv_C. The latest launch date on which minimal $\Delta v_R < \Delta v_C$ is the estimated launch season closure date. Figure 2 summarizes results from this analysis.

The estimated 28 November 2011 launch season closure date inferred from Figure 2 data is 8

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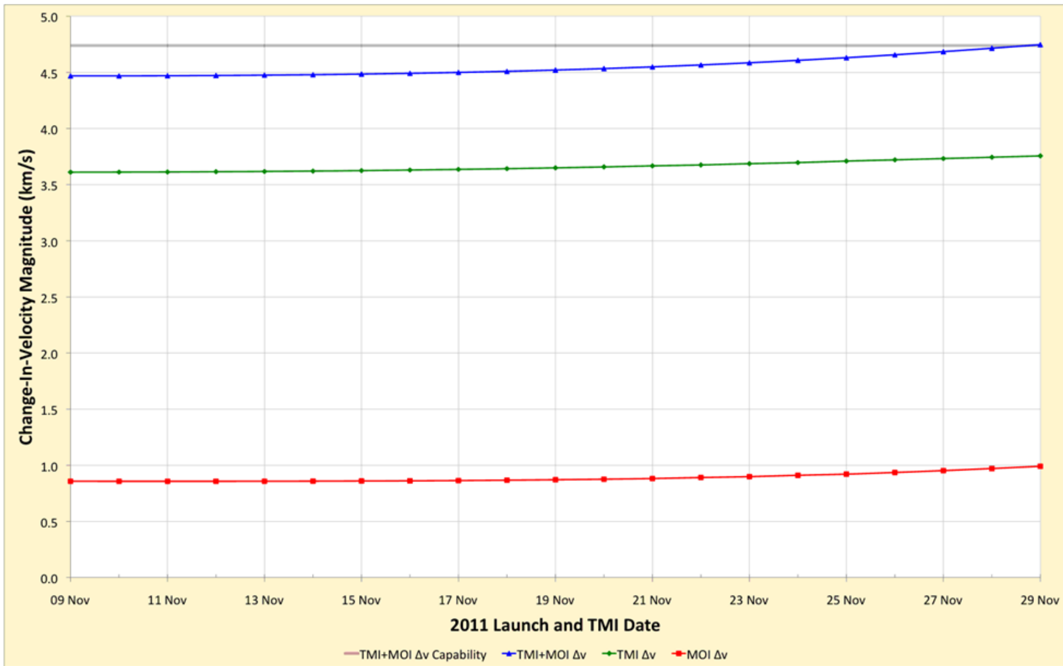

Figure 2. The blue curve in this plot chronicles growth in Δv_R as *Phobos-Grunt* launch date is delayed from its actual occurrence on 8 November 2011. On 29 November 2011, the $\Delta v_R = \Delta v_{TMI} + \Delta v_{MOI}$ curve first exceeds the Δv_C limit plotted in gray. Estimated launch season closure is therefore 28 November 2011. For reference, the green curve plots growth in Δv_{TMI}, and the red curve plots growth in Δv_{MOI}.

days later than that previously cited from a RussianSpaceWeb.com report. This deviation may be due to intentionally optimistic assumptions associated with Figure 2 data. However, Roscosmos head Vladimir Popovkin is quoted as stating on 14 November 2011 that *Phobos-Grunt*'s window for Mars departure would close in early December[6]. The 28 November 2011 launch season closure estimate may therefore be considered "in the ballpark", particularly if Δv_{MOI} can be reduced by techniques such as increasing H_A.

But the entire discussion of *Phobos-Grunt* launch season closure is academic, if not intentionally misleading, in the context of actual launch having occurred on 8 November 2011. As will be demonstrated in the next two sections, that launch imposes a latest mission recovery date well before even 20 November 2011.

[6]Reference Emily Lakdawalla's blog at http://www.planetary.org/blog/article/00003261/.

Estimated Single-Impulse TMI Latest Mission Recovery Date

The total change-in-velocity requirement $\Delta v_R'$ associated with *Phobos-Grunt* mission recovery following actual launch on 8 November 2011 is the sum of two components such that $\Delta v_R' = \Delta v_{TMI}' + \Delta v_{MOI}$. For a specified TMI date initiating mission recovery, the Δv_{MOI} component is identical to that required by nominal mission prelaunch planning for that date. But the $\Delta v_{TMI}'$ component will generally require steering through the angle β in order to turn the geocentric *Phobos-Grunt* Earth parking orbit plane into one containing the required Earth departure asymptote bound for Mars. Assuming this steering is done simultaneously with the TMI geocentric speed increase (the most propellant-conservative single-impulse strategy), associated vector geometry is illustrated in Figure 3.

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Astrodynamics

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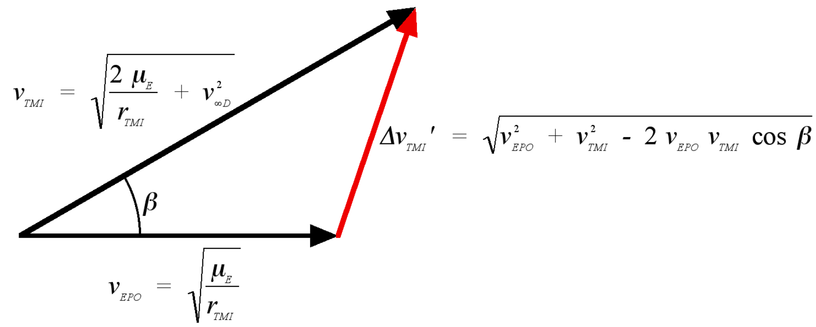

Figure 3. This geocentric velocity vector diagram forms a triangle with sides whose lengths are geocentric speeds. The first side (smaller black arrow) has speed in Earth parking orbit v_{EPO} before TMI. The second side (larger black arrow) has speed in the Earth departure hyperbola v_{TMI} immediately after TMI. The third side (red arrow) has the change-in-velocity magnitude $\Delta v_{TMI}'$ associated with TMI as computed by the law of cosines. When the steering angle β is zero, $\Delta v_{TMI}'$ is simply v_{TMI} minus v_{EPO}, as previously computed for a nominal mission's Δv_{TMI}.

Computing β is not a trivial process. Regular USSTRATCOM updates to the as-flown *Phobos-Grunt* trajectory in its Earth parking orbit are processed to determine the spacecraft's angular momentum vector $\boldsymbol{c}$ in geocentric inertial space. Although $\boldsymbol{c}$ is normal to *Phobos-Grunt*'s orbit plane at any instant, excess mass about Earth's equator causes $\boldsymbol{c}$ to precess westward at about 5.4° per day. Meanwhile, asymptotic Earth departure velocity $\boldsymbol{v}_{\infty D}$ is slowly changing with time in geocentric inertial space due to Earth and Mars heliocentric motion. Because it measures the angle between a vector and a plane, β is equivalent to $\boldsymbol{v}_{\infty D}$ latitude with respect to the *Phobos-Grunt* Earth parking orbit plane at a specified mission recovery TMI time. Adopting the sign convention "β is positive when $\boldsymbol{v}_{\infty D}$ points into the hemisphere whose pole is $\boldsymbol{c}$", the following equation computes its value[7].

$$\beta = 90° - \mathrm{acos}\left\{\frac{\boldsymbol{c} \bullet \boldsymbol{v}_{\infty D}}{c\, v_{\infty D}}\right\}$$

The foregoing computational pedigree applies to hypothetical *Phobos-Grunt* mission recovery data summarized in Table 1. From these data, it is evident a single-impulse TMI *Phobos-Grunt* mission recovery option existed for little more than 3 days after actual launch.

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[7]A similar quantity called "β" is routinely used in planning International Space Station (ISS) operations, and it has the same sign convention. Of course, this parameter defines $\boldsymbol{c}$ with respect to ISS orbit elements. The only fundamental difference is the ISS β context replaces $\boldsymbol{v}_{\infty D}$ with the Sun's geocentric position vector.

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Table 1. Hypothetical *Flagman* propulsion requirement $\Delta v_R'$ for single-impulse TMI *Phobos-Grunt* mission recovery is assessed on TMI dates following actual launch on 8 November 2011. Values for Δv_{TMI} are included to compare with corresponding $\Delta v_{TMI}'$ values because the former assume steering angle β is zero. Since increasing β rapidly inflates $\Delta v_{TMI}'$ as mission recovery TMI is postponed, $\Delta v_R'$ exceeds *Flagman* propulsive capability Δv_C = 4.739 km/s before 12 November 2011.

Parameter	2011 Date at Hypothetical Mission Recovery TMI			
	9 Nov	10 Nov	11 Nov	12 Nov
2012 Mars Arrival	11 Sep	11 Sep	12 Sep	12 Sep
β (deg)	+0.260	+3.790	+7.503	+11.204
Δv_{TMI} (km/s)	3.611	3.612	3.613	3.615
$\Delta v_{TMI}'$ (km/s)	3.611	3.665	3.816	4.052
Δv_{MOI} (km/s)	0.858	0.858	0.857	0.857
$\Delta v_R'$ (km/s)	4.469	4.523	4.673	4.909

Inertial dynamics giving rise to β variations can be visualized by projecting snapshots of the precessing *Phobos-Grunt* Earth parking orbit plane onto the geocentric celestial sphere, along with variations in the direction of $\boldsymbol{v}_{\infty D}$. Like the Figure 1 Earth map, north is up and south is down in the Figure 4 celestial sphere plot. In this analogy, Figure 1 latitude is replaced by Figure 4 declination with respect to the Earth mean equator of Julian epoch J2000.0. Likewise, Figure 1 longitude is replaced by right ascension with respect to the mean equinox at J2000.0 in Figure 4. Because Figure 4 shows the inside of a celestial sphere rather than Earth's surface, east is left and west is right. Consequently, the *Phobos-Grunt* orbit plane drifts rightward with time in Figure 4.

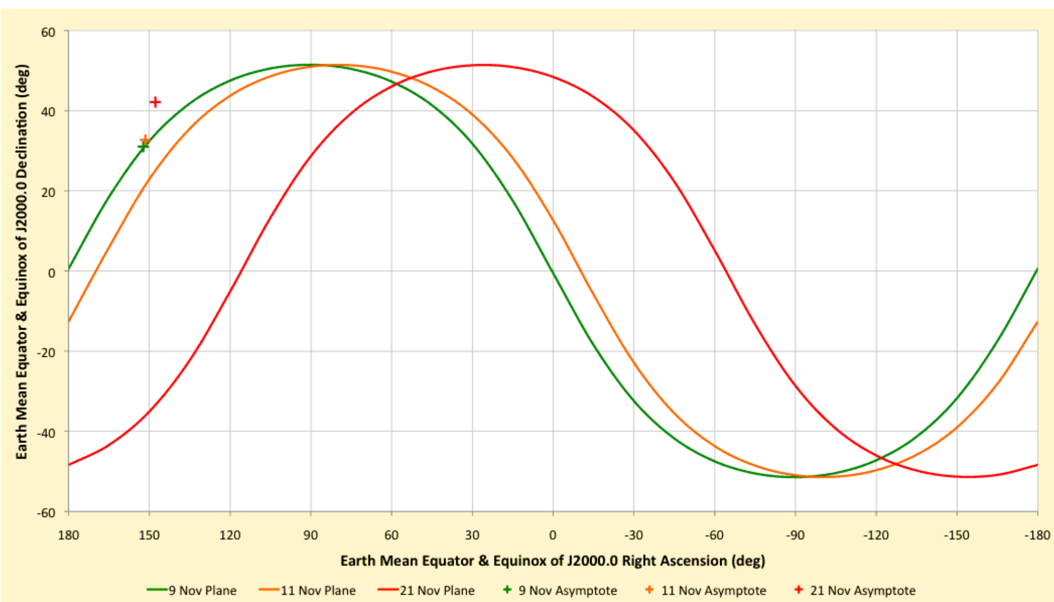

Figure 4. Snapshots of the actual *Phobos-Grunt* Earth parking orbit plane on 9 November 2011 (green line), 11 November 2011 (orange line), and 21 November 2011 (red line) are projected onto the geocentric celestial sphere (truncated at declination magnitudes exceeding 60°) defined by Earth's mean equator and equinox of Julian epoch J2000.0. These snapshots illustrate westward precession of the plane with time. In addition, slowly changing Earth asymptotic departure directions for Mars are plotted for 9 November 2011 (green "+"), 11 November 2011 (orange "+"), and 21 November 2011 (red "+"). Asymptotic departure direction lies closest to the *Phobos-Grunt* orbit plane on 9 November 2011, shortly after actual launch. Only then are TMI propulsive steering losses due to increasing β negligible. By 11 November 2011, these losses are about to exceed estimated *Flagman* capability to recover the mission with a single TMI impulse.

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At the 5.4° per day precession rate, about 5 additional weeks would be required for the 21 November 2011 plane to precess near the plotted asymptotic departure directions in Figure 4. By that time in late December 2011, Earth will have phased too close to Mars opposition for *Phobos-Grunt* mission recovery with *Flagman* propulsive capability. Note also the possibility that asymptotic departure declination can drift so far north (or south) that it exceeds the orbit plane's northern (or southern) declination limit. Under such geometry, TMI β might never be sufficiently near zero, regardless of orbit plane precession in right ascension.

Estimated Three-Impulse TMI Latest Mission Recovery Date

Now assume *Phobos-Grunt* could have performed TMI with three impulses. The first impulse would actually be performed with two *Flagman* burns, the first burn depleting its drop tanks. A four-burn *Flagman* TMI capability enables a strategy whose total change-in-velocity requirement is $\Delta v_R''$. Under this strategy, *Phobos-Grunt* mission recovery following actual launch on 8 November 2011 is the sum of four components such that $\Delta v_R'' = \Delta v_{HA} + \Delta v_{NPC} + \Delta v_{TMI}'' + \Delta v_{MOI}$. The first three components of $\Delta v_R''$ comprise TMI in the foregoing expression, while the Δv_{MOI} component is identical to that required by nominal mission prelaunch planning for launch on the recovery date.

The three-impulse TMI takes maximum advantage of two propellant-conserving precepts in astrodynamics. First, a change in speed is best performed at the fastest possible initial speed. In the TMI context, this entails performing posigrade impulses at perigee. Second, a change in direction is best performed at the slowest possible speed, dictating β be reduced to zero at apogee.

In accord with these precepts, the first "height adjust" impulse Δv_{HA} is posigrade and raises the assumed initial Earth parking orbit's circular height at 274 km to some minimal apogee radius r_A. Since there is no distinct perigee in the initial orbit, the Δv_{HA} impulse establishes a perigee consistent with the required Earth departure hyperbola. The second "plane change" impulse Δv_{NPC} is performed at r_A and achieves $\beta = 0$ at the next perigee without any change in speed. The third $\Delta v_{TMI}''$ impulse is posigrade and performed at that next perigee, whose 274 km height is unaltered from the original parking orbit. Readers familiar with "anytime" lunar return trajectory planning for the Constellation Program will recognize the three-impulse TMI recovery as a fundamentally similar strategy.

As r_A increases with increased Δv_{HA}, the Δv_{NPC} required to null a specified β decreases. The downside to this trend is orbit period increases with r_A, delaying $\Delta v_{TMI}''$ and causing all three TMI components to increase. Consequently, r_A is increased no more than necessary to reduce $\Delta v_R''$ within *Flagman*'s $\Delta v_C = 4.739$ km/s.

In assessing the three-impulse TMI, it is important to recognize that the first Δv_{HA} impulse at time t_1 will place r_A well above a geostationary orbit's radius, all but halting westward precession of the resulting orbit. Although β will continue to increase after t_1, it will do so only during brief near-perigee intervals immediately after t_1 and before $\Delta v_{TMI}''$ at time t_3 and while the Earth departure asymptote drifts slowly northwestward per Figure 4. In a continuing effort to impart maximum possible *Phobos-Grunt* mission recovery capability, β is therefore frozen at its t_1 value during each assessment.

A second consideration when assessing three-impulse TMI is growth in all but the Δv_{NPC} component of $\Delta v_R''$ during the interval from t_1 to t_3. But $\Delta v_R'' - \Delta v_{NPC} = \Delta v_{HA} + \Delta v_{TMI}'' + \Delta v_{MOI}$ is just another way of computing Δv_R in a context specific to three-impulse TMI. To compute Δv_R at a specified t_3, a least squares cubic polynomial is fit to all Δv_R points plotted in Figure 2. If t_3 is

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expressed as a November 2011 UTC decimal day, the following cubic reproduces all Figure 2 Δv_R values in km/s units to at least 0.001 precision.

$$\Delta v_R^* = 0.00001565741 * t_3^3 - 0.00001729571 * t_3^2 - 0.00392343 * t_3 + 4.494745$$

During each three-impulse TMI assessment, the minimum r_A is sought for which $\Delta v_{NPC} < \Delta v_C - \Delta v_R^*$. At any r_A being assessed, t_3 is one orbit period after t_2. This period is computed assuming perigee height remains at 274 km. Three-impulse TMI assessment results are presented in Table 2.

Table 2. Hypothetical three-impulse TMI *Phobos-Grunt* mission recovery is assessed for TMI dates following actual launch on 8 November 2011 and loss of single-impulse TMI mission recovery capability three days later. A minimal apogee radius r_A is targeted by the first Δv_{HA} posigrade impulse at time t_1 such that $\Delta v_R''$ does not exceed the previously computed Δv_C = 4.739 km/s *Flagman* capability. The second Δv_{NPC} impulse can then null the TMI steering angle β such that the third $\Delta v_{TMI}''$ impulse at time t_3 is purely posigrade. Values for $\Delta v_R^* = \Delta v_R'' - \Delta v_{NPC}$ are from a polynomial approximation to Δv_R data plotted in Figure 2.

Parameter	2011 UTC at Hypothetical Mission Recovery Δv_{HA} (t_1)					
	12.0 Nov	13.0 Nov	14.0 Nov	15.0 Nov	16.0 Nov	17.0 Nov
2012 Mars Arrival	12 Sep	13 Sep	13 Sep	14 Sep	14 Sep	15 Sep
β (deg)	+11.204	+15.048	+18.875	+22.805	+26.706	+30.677
Δv_R^* (km/s)	4.474	4.479	4.486	4.498	4.515	4.545
r_A (km)	51,000	71,000	92,000	117,000	147,000	196,000
Δv_{NPC} (km/s)	0.262	0.257	0.251	0.239	0.224	0.193
t_3 (2011 Nov UTC)	12.564	13.881	15.262	16.771	18.453	20.715
$\Delta v_R''$ (km/s)	4.736	4.736	4.737	4.737	4.739	4.738

Table 2 confirms *Flagman*'s Δv_C constraint imposes a runaway increase in r_A in order to decrease Δv_{NPC} as β and Δv_R^* increase with postponed t_1 and t_3, respectively. To be a viable mission recovery option, a three-impulse TMI must be initiated such that t_1 is earlier than 18.0 November 2011 UTC. By that time, r_A has grown to the point t_3 falls after 29 November 2011. As noted in Figure 2's caption, a t_3 this late drives Δv_R to exceed Δv_C, and no *Flagman* capability is available to perform Δv_{NPC}.

Conclusion

The *Phobos-Grunt* mission's failure to achieve TMI serves as an empirical demonstration of the difference between a launch season and the interval in which a mission may be recovered after an otherwise nominal launch into LEO leads to delayed departure for deep space. An inexorable mission recovery countdown clock is running during the delay. In the *Phobos-Grunt* case, this clock expired 3 to 9 days after actual launch, depending on the number of TMI burns mission managers were willing to perform. This estimated mission recovery interval is but a fraction of the mission's 20-day launch season, even if the season is assumed to have opened on the day *Phobos-Grunt* launched. This situation was never clearly communicated as it played out in November 2011.

But there are broader implications from the *Phobos-Grunt* mission recovery scenario. A similar countdown clock is set following the first of multiple launches required to build up sufficient mass in LEO for departure to any interplanetary destination. An adequately padded launch campaign timeline manages the risk of late departure, but additional exposure to the LEO environment carries its own risks.

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Reusable infrastructure in LEO, a propellant depot being a notable example, will be particularly challenged to ensure β is sufficiently near zero at a time when an interplanetary destination is properly phased with Earth. This may require deploying such reusable infrastructure at a sufficiently high orbit inclination to guarantee all conceivable Earth departure asymptote declinations are accommodated. Sufficiently high inclination will generally incur a performance penalty for all launches supporting the reusable infrastructure's logistics. It may therefore be preferable to adopt single-use, mission-specific architectures for multiple-launch interplanetary mission campaigns if they must be staged in LEO.

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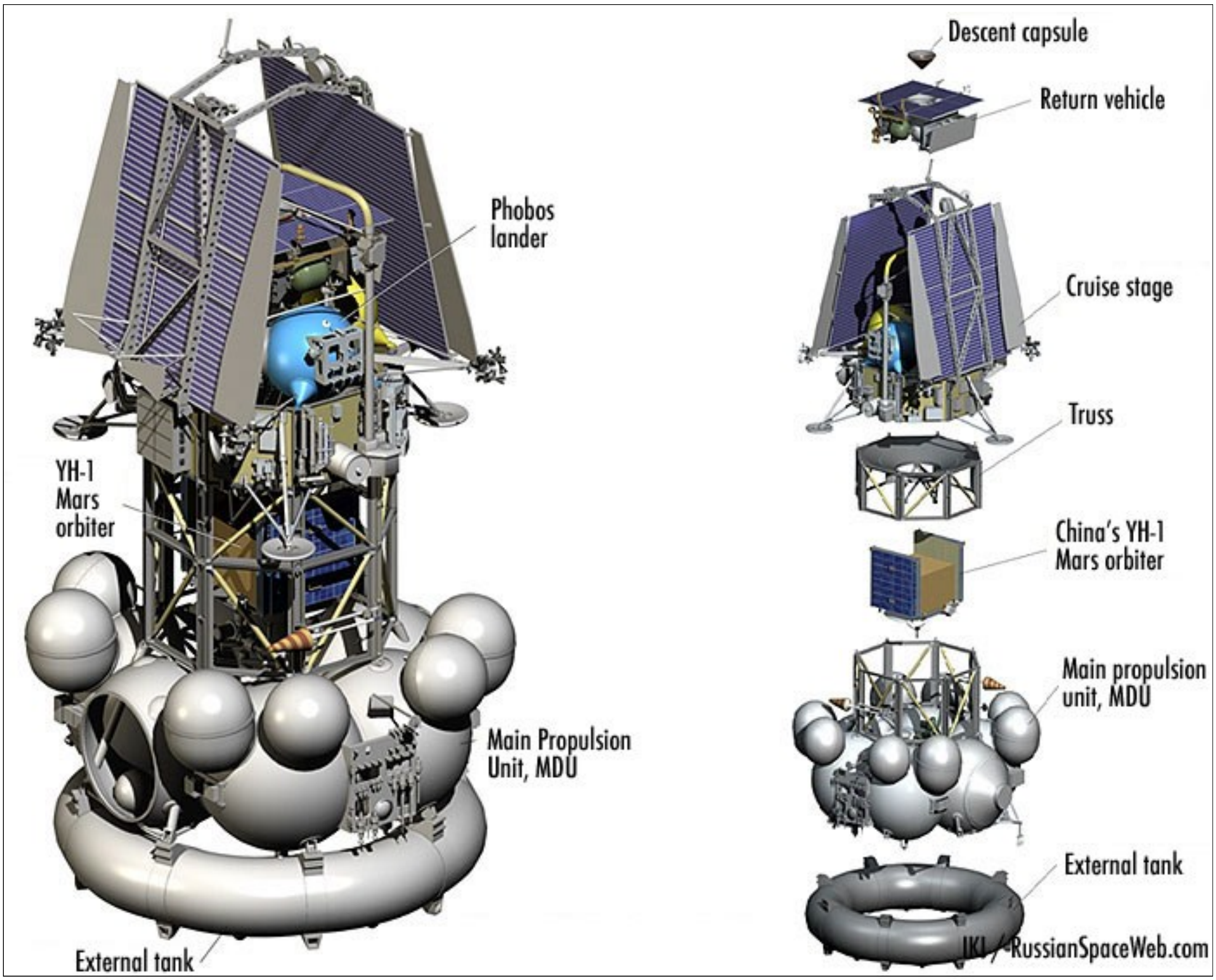

Above: The final architecture of the Phobos-Grunt spacecraft and its major components as of 2011. Credit: IKI (Russian Space Research Institute).

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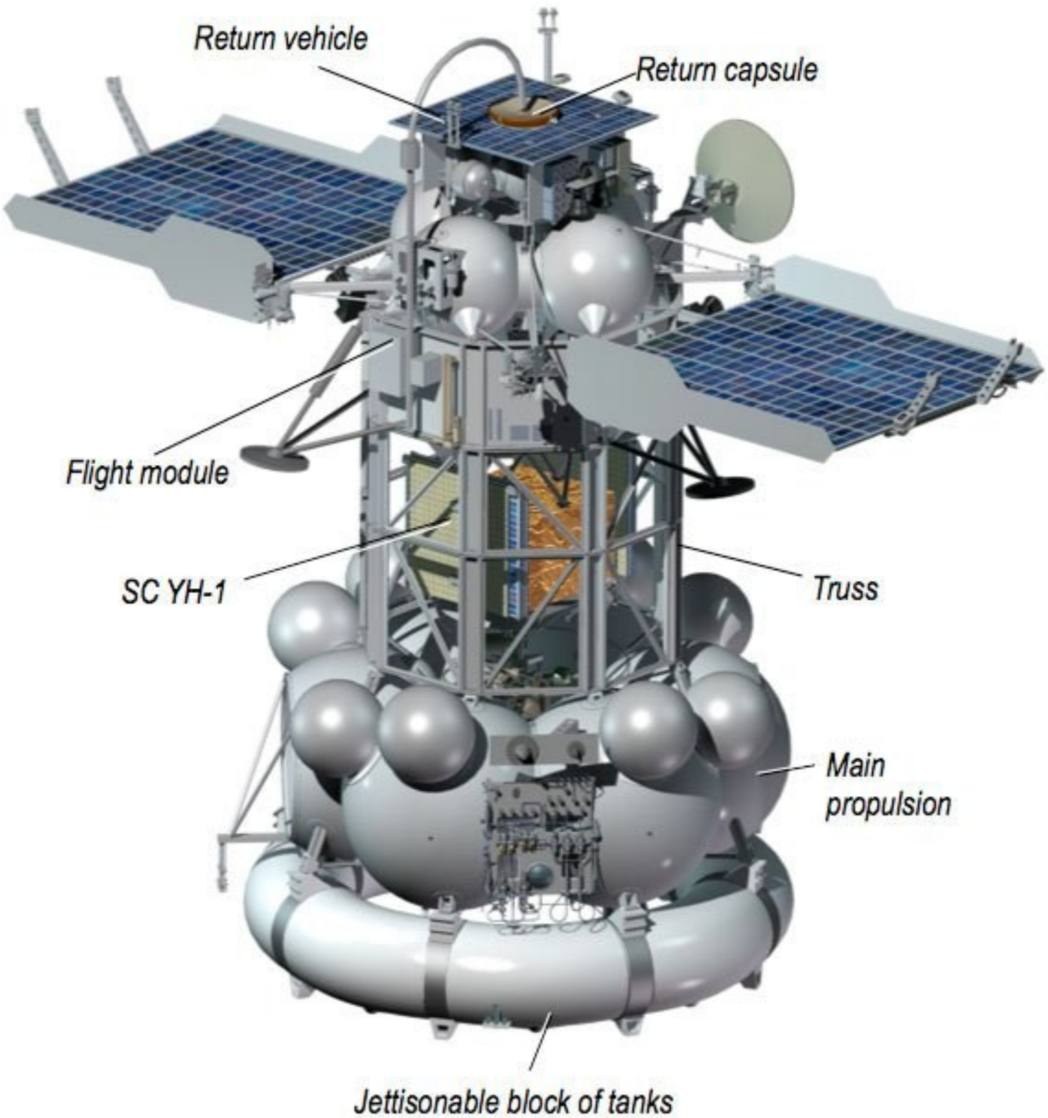

Left: Phobos-Grunt (alternatively Fobos-Grunt) is a Russian mission designed to land on the martian moon Phobos and return a sample to Earth. The primary scientific objective is to analyze the sample on Earth to understand the origin and reconstruct the history of Phobos. Specific objectives will be to analyze the composition of the material returned and to determine how it related to other material in the solar system, if it contains any particles ejected from the martian surface, protosolar matter, or organic material, if it has been differentiated and to what degree, and the ages of the sample. A robotic arm will collect approximately 100 to 200 grams of samples and deposit them in a return capsule which will be launched back to Earth. Phobos-Grunt will be launched with a Chinese Mars orbiter aboard, Yinghuo-1. Image and text source for this page: http://nssdc.gsfc.nasa.gov/planetary/image/phobos_grunt.jpg. Image and text credit for this page: NASA.

Left: This is a full-scale mockup of the Phobos lander, the Mars departure vehicle, and the Earth return capsule. The Russian spacecraft was supposed to collect samples of soil on Mars' moon Phobos and bring the samples back to Earth for detailed study. Credit: CNES.

APR
E-Publication

Aerospace Projects Review

Aerospace Projects Review (APR) is presented by Scott Lowther, whose unique electronic publication is described as a "journal devoted to the untold tales of aerospacecraft design." More information may be found at the following address:
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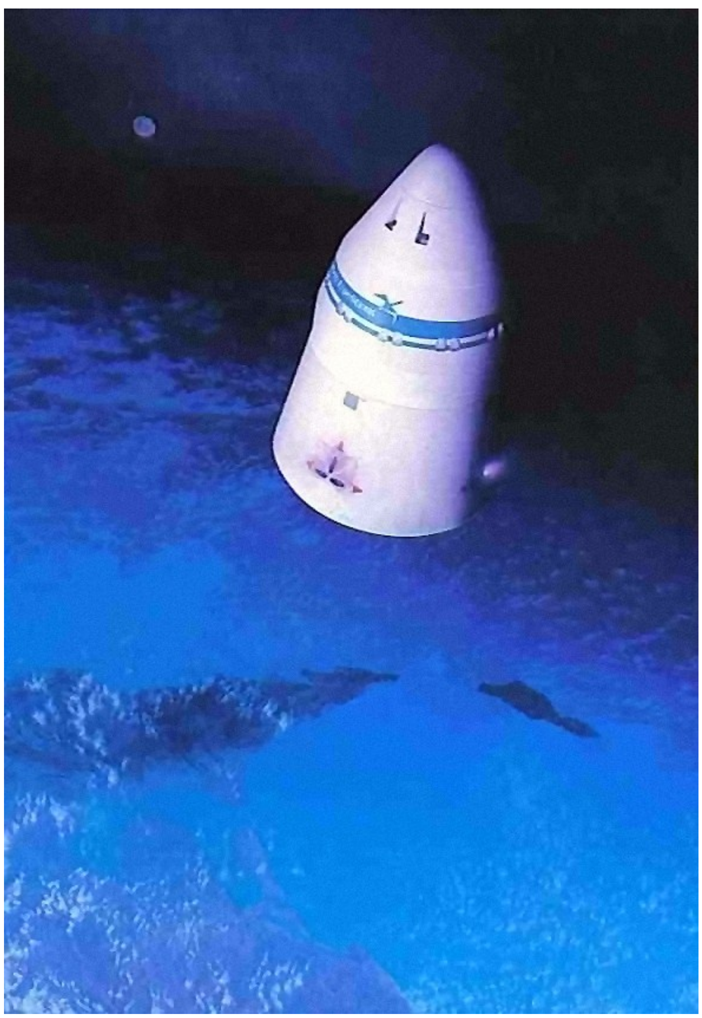
Right: Artwork depicting the Phoenix-E in orbit, in Society Expeditions colors. Image credit: Scott Lowther.

Phoenix-E

SCOTT LOWTHER

Man has been travelling into space for half a century with some regularity, but the vast majority of these trips have been at government expense. Many people have wanted to be space tourists, to go on vacation to an orbiting Space Hilton or a cruise around the Moon, but until quite recently, the whole idea of space tourism has been largely laughed at. As far back as the late 1960s the likes of Barron Hilton (of the Hilton hotel chain) and Krafft Ehricke gave serious contemplation to space hotels, but it has only been within the last half decade or so that space tourism has been considered a viable possibility in the aerospace community.

One thing has kept the concept from gaining acceptance: cost. A few super-rich adventurers have indeed gone on vacations in space… at the cost of $20 million or so for a week in cramped space stations not designed for luxuries or comfort. Even now, as suborbital tourist craft are being actually built and test flown, prices are ranging from $100,000 to $200,000 for just a few minutes of zero-g... working out to hundreds of dollars per second. While this



definitely puts space tourism within the grasp of a far vaster pool of vacationers than the $20 million price point, it is still beyond the reach of most people, and as "space tourism," it falls rather short of the real goal of many... orbit. In order to achieve that goal, an orbital vehicle would need to be developed that would be orders of magnitude cheaper to build, operate and maintain than normal space launch systems.

One such vehicle was designed nearly thirty years ago. Society Expeditions, founded in 1974, was a travel company that focused on exotic cruises to locales such as Antarctica, the Northwest Passage and the Middle East, all with an eye for luxury. So it was perhaps not surprising that in April of 1985 they announced that a new venture (under the aegis of the "Space Travel Company") would be offering jaunts into low Earth orbit. "Project Space Voyage" would have its maiden voyage on October 12, 1992, the 500th anniversary of Columbus' discovery of the Americas. The space vehicle would be the Phoenix-E (E for Excursion): a vertical take-off and landing (VTOL) single-stage-to-orbit rocket vehicle to be designed and built by Pacific American Launch Systems, owned by Gary Hudson. The Phoenix-E would require a crew of five and carry twenty passengers in luxury accommodations. Maximum acceleration would be 3 g's, and each passenger would have a large window. The journey

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would be a simple trip to orbit, starting from Vandenberg in California. The craft would spend 8 to 12 hours in orbit. It would then re-enter and land near the launch site, using rockets for a powered vertical landing. The ticket price was $52,000.

It was expected that development of the Phoenix-E would take three and a half years, followed by fifty test flights over a year and a half. The Space Travel Company (STC) would have exclusive rights to two Phoenix-E's for five years, with the option of purchasing ten craft. Development of the Phoenix-E was expected to cost up to $250,000,000, part of which was to be raised by selling stock, part by selling seats in advance. As of January 1986, at least 150 people had paid a $5,000 deposit. STC expected to launch up to 5,000 passengers by 1997. Whether this number was based on serious market studies or was just what they hoped to attain is unclear.

The Phoenix-E, a modification of the Phoenix single-stage-to-orbit (SSTO) that Hudson had been developing since 1982 (the Phoenix-C being the cargo version), was in many ways similar to but much smaller than the ROMBUS SSTO design. ROMBUS was designed in 1962 by Phillip Bono of Douglas Aircraft to orbit nearly a million pounds of payload. As with Phoenix, ROMBUS featured a truncated conical

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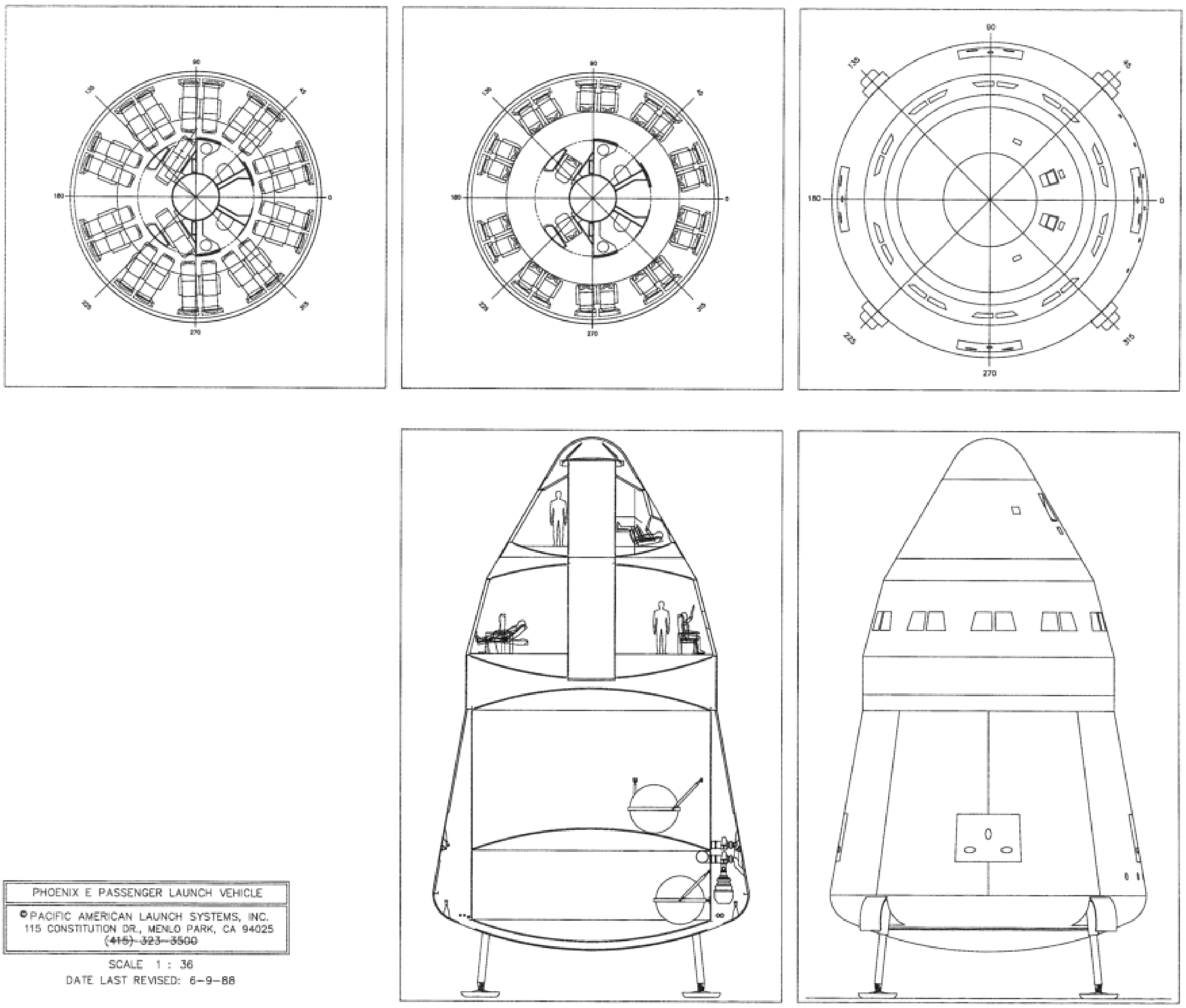
Below: Diagram courtesy Gary Hudson, via Tom Brosz.



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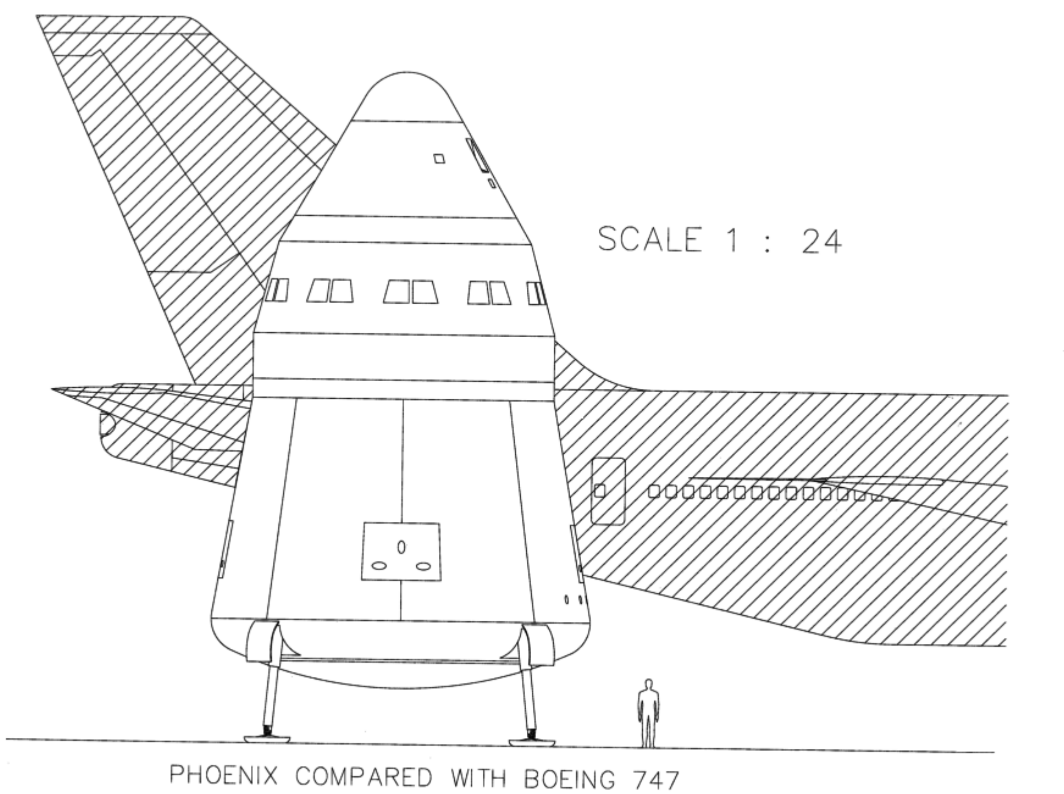
propulsion and propellant module with a toroidal aerospike engine, giving automatic altitude compensation from sea level to space. Both the Phoenix and the ROMBUS would launch vertically and re-enter tail first, with the blunt aerospike engine forming the heat shield. Both would use a small amount of the remaining launch propellant for a vertical landing, with deployable landing gear allowing touchdowns on concrete landing pads. Unlike ROMBUS, Phoenix would use "slush" hydrogen and oxygen; by lowering the propellant temperatures to their freezing points, the bulk propellant densities would be increased by 14% or more, aiding with the mass ratio of the vehicle. Additionally, the rocket engines would have two operating modes. Mode 1, used from launch to about 7,500 feet per second, would use an oxygen-rich mixture ratio of 13:1, with Mode 2 using a hydrogen-rich mix ratio of 7:1. Mode 1 would reduce specific impulse to 355 seconds, but the benefit was that low-density hydrogen would be traded for high density oxygen, greatly reducing the mass of tankage and associated structures. Mode 2 would have a higher specific impulse (Isp) of 463 seconds. The Phoenix "Mainstage" had a maximum diameter of 384 inches, a structural weight of 25,000 pounds and a propellant load of 400,000 pounds. The Mainstage was basically a self-contained vehicle, with everything atop it being payload, whether that was unmanned cargo or a module with a cockpit and twenty passengers. The net payload weight that the Mainstage could inject into orbit was 20,000 pounds. While composites would be used, the primary structural material was to be aluminum. Overall vehicle height would be 57 feet while sitting on its four deployable landing legs. Gross liftoff weight would be about 454,600 pounds.

While STC failed to raise the funds needed to bring the Phoenix-E to life, the design continued to evolve over the next decade or so. The board of directors of the STC included Maxwell Hunter II, formerly of McDonnell-Douglas, where he had headed up development of the Thor intermediate range ballistic missile (IRBM), the Delta space launcher and the S-IVb stage of the Saturn V. At the time, Hunter worked at Lockheed, and in 1988 developed the design of the "X-Rocket," a conical SSTO. In 1989 Hunter refined the design further on his own, creating the SSX (Space Ship Experimental), a design meant for cheap space launch for the Space Defense Initiative. Together with the Phoenix designs, Hunter's SSX helped lead the Ballistic Missile Defense Organization to fund development of the Delta Clipper concept, producing the DC-X test vehicle. Society Expeditions filed for bankruptcy in 2004.

More on the Douglas ROMBUS SSTO can be found in issue V2N6 of Aerospace Projects Review, available at: www.aerospaceprojectsreview.com.

Below: Diagram courtesy Gary Hudson, via Tom Brosz.



EAA and EAA Chapter 12 Information

Chapter Mission

The Experimental Aircraft Association's Chapter 12, located at Ellington Field in Houston, is an organization that promotes all forms of recreational aviation. The organization includes interest in homebuilt, experimental, antique and classic, warbirds, aerobatic aircraft, ultra lights, helicopters and commercially manufactured aircraft and the associated technologies.

This organization brings people together with an interest in recreational aviation, facilitating social interaction and information sharing between aviation enthusiasts. Many of the services that EAA offers provide valuable support resources for those that wish develop and improve various skills related to aircraft construction and restoration, piloting, aviation safety, and aviation education. Every individual and organization with an interest in aviation and aviation technology is encouraged to participate (EAA membership is not required, but encouraged). Meetings are generally from 6:30 PM to 9 PM at Ellington Field in Houston Texas. We welcome everyone. Come as you are and bring a guest; we are an all aviation friendly organization!

Ideas for a meeting? Contact Richard at rtsessions “at” earthlink.net, Chapter web site: www.eaa12.org
Experimental Aircraft Association web site: www.eaa.org

Scheduled/Preliminary Chapter 12 Event/Meeting Ideas and Recurring Events:
Monthly Meeting: Chapter 302, 2nd Saturday, 10 AM, Lone Star Builder’s Center, Lone Star Executive, Conroe TX
1st Saturday of each month – La Grange TX BBQ Fly-In, Fayette Regional (3T5)
1st Saturday – Waco/Macgregor TX (KPWG), Far East Side of Field, Chap 59, Pancake Breakfast with all the goodies 8-10 AM, Dale Breedlove, jdbvmt “at” netscape.com
2nd Saturday – Lufkin TX Fajita Fly-In (LFK)
2nd Saturday – New Braunfels TX Pancake Fly-In
3rd Saturday – Wings & Wheels, 1941 Air Terminal Museum, Hobby Airport, Houston TX
3rd Saturday – Jasper TX BBQ Lunch Fly-In (JAS)
3rd Saturday – Tyler TX Breakfast Fly-In, 8-11, Pounds Field (TYR)
4th Saturday – Denton TX Tex-Mex Fly-In
4th Saturday – Leesville LA Lunch Fly-In (L39)
4th Saturday – Shreveport LA Lunch Fly-In (DTN)
Last Saturday – Denton Fly-In 11AM-2 PM (KDTO)

In our May 2011 issue we started our series EAA/AIAA profiles in general and experimental aviation with Lance Borden, who is rebuilding his Inland Sport airplane, an aircraft manufactured by his grandfather’s 1929 - 1932 company. The second in this series was a profile of Paul F. Dye. The third profile will probably appear in our next issue. This series was suggested by Richard Sessions of EAA Chapter 12.

EAA is the Experimental Aircraft Association. The Houston Chapter is #12, one of the earliest created among the hundreds of chapters.

www.eaa12.org.

*Left: RV-9A on the ramp at Wings & Wheels of August 20, 2011, at the 1940 Air Terminal Museum at Hobby Airport in Houston, Texas. From Wikipedia: “The **Van's RV-9** and **RV-9A** are two-seat, single-engine, low-wing homebuilt airplanes sold in kit form by Van's Aircraft. The RV-9 is the tail-wheel equipped version while the RV-9A features a nose-wheel. The RV-9 was built around a newly-designed high aspect ratio wing, featuring a Roncz airfoil. It is similar in size and weight to RV-6 and is externally similar to the RV-6 and the RV-7.” Image credit: 1940 Air Terminal Museum (www.1940airterminal.org).*

Current Events

TEDx NASAJSCWomen
x = independently organized TED event

Right: Astronaut Dottie-Metcalf-Lindenberger. Image credit: www.ted.com.

Houston, TX, United States
December 1st, 2011

Right: Notes from the program document for this recent TEDx event. One of the event organizers was Ted Kenny/ NASA-JSC, our current AIAA Houston Section history technical committee Chair. Reporter: Douglas Yazell.

TEDx NASA/JSC Women

December 1, 2011
Teague Auditorium

x = independently organized TED event
Technology, Entertainment, and Design (TED)
"Ideas Worth Spreading"
www.ted.com

Reshaping the Future: Resilience, Relationships, Rebirth, and Reimagine

TED is a small nonprofit devoted to Ideas Worth Spreading. It started in 1984 as a conference bringing people together from three worlds: Technology, Entertainment, Design. Since then its scope has become even broader.

This event was open to everyone (women and men) who support and encourage women in their lives.

9:00 AM

Sherry Hatcher & Courtney McManus (MC: Welcome)

Ellen Ochoa (Welcome)

Jessie Fernandez (First Joining NASA)

Cindy McArthur (NASA Education: Building the Next Generation of Explorers

Lora Bailey (Engineering Innovation)

Dottie Metcalf-Lindenberger (STEM Education: The Root of our Future)

10:00 AM

Live Feed from New York City

11:55 AM

Cady Coleman (Why 6 Months in Space is Not Enough)

Julie Robertson (Experiments that Can't be Done on Earth)

Keiko Nakamura-Messenger (Exploring the Solar System with a Microscope)

Dolores Petropoulos (Re-Imagining)

12:45 PM

Lunch with Leaders

Look for these videos on the related TEDx web site. Start searching for that at ted.com.

End

Current Events

Above: a cropped image from JSC2012-E-017833. Image credit: NASA.

Above: JSC2012-E-017837 (4 Jan. 2012) --- Multiple images of the International Space Station flying over the Houston area have been combined into one composite image to show the progress of the station as it crossed the face of the moon in the early evening of Jan. 4. The station, with six astronauts and cosmonauts currently aboard, was flying in an orbit at 390.8 kilometers (242.8 miles). The space station can be seen in the night sky with the naked eye and a pair of field binoculars may reveal some detail of the structural shape of the spacecraft. Station sightings in the area will be possible again (weather permitting) Friday, Jan. 6, beginning at 6:11 p.m. CST. Viewing should be possible for approximately six minutes as the station moves from 10 degrees above west-northwest to 10 degrees above south-southeast. The maximum elevation will be 44 degrees. To find sighting details by city, visit: http://go.usa.gov/81R. Equipment used by the NASA photographer, operating from NASA's Johnson Space Center, was as follows: Nikon D3S, 600mm lens and 2x converter, Heavy Duty Bogen Tripod with sandbag and a trigger cable to minimize camera shake. The camera settings were as follows: 1/1600 @ f/8, ISO 2500 on High Continuous Burst. Photo credit: NASA.

Staying Informed

Right: ISS030-S-001 (April 2011) --- The International Space Station (ISS) program is completing the transition from assembly to full utilization as humankind celebrates the golden anniversary of human space exploration. In recognition of these milestones and especially of the contribution of those whose dedication and ingenuity make spaceflight possible, a fully assembled ISS is depicted rising above a sunlit Earth limb. Eastward of the sunlit limb, the distinctive portrayal of Earth's surface illuminated by nighttime city lights is a reminder of mankind's presence on the planet, most readily apparent from space only by night, and commemorates how human beings have transcended their early bonds throughout the previous 50 years of space exploration. The ISS, a unique space-based outpost for research in biological, physical, space and Earth sciences, in the words of the crew members, is an impressive testament to the tremendous teamwork of the engineers, scientists and technicians from 15 countries and five national space agencies. The six crew members of Expedition 30, like those who have gone before them, express that they are honored to represent their countries and the ISS team in conducting research aboard the station and adding to the body of knowledge that will enable the world's space faring countries to more safely and more productively live, work and explore outer space, paving the way for future missions beyond low Earth orbit, and inspiring young people to join in this great adventure. Image credit: NASA.

Who is on ISS now? As of February 25, 2012, it is the crew of Expedition 30.

Above: ISS030-S-002 (19 July 2011) --- Expedition 30 crew members take a break from training at NASA's Johnson Space Center to pose for a crew portrait. Pictured on the front row are NASA astronaut Dan Burbank, commander; and Russian cosmonaut Oleg Kononenko, flight engineer. Pictured from the left (back row) are Russian cosmonauts Anton Shkaplerov and Anatoly Ivanishin; along with European Space Agency astronaut Andre Kuipers and NASA astronaut Don Pettit, all flight engineers. Photo credit: NASA and International Space Station partners.

Editor's note: Daniel Adamo was already sending Figures 1 and 2 to an astrodynamics contact list on December 18, 2011. Sun-grazing comet Lovejoy stunned the world of astronomy by surviving its spectacular encounter with the Sun on December 16, 2011.

Staying Informed

Left: Image credit: Daniel R. Adamo, Astrodynamics Consultant.

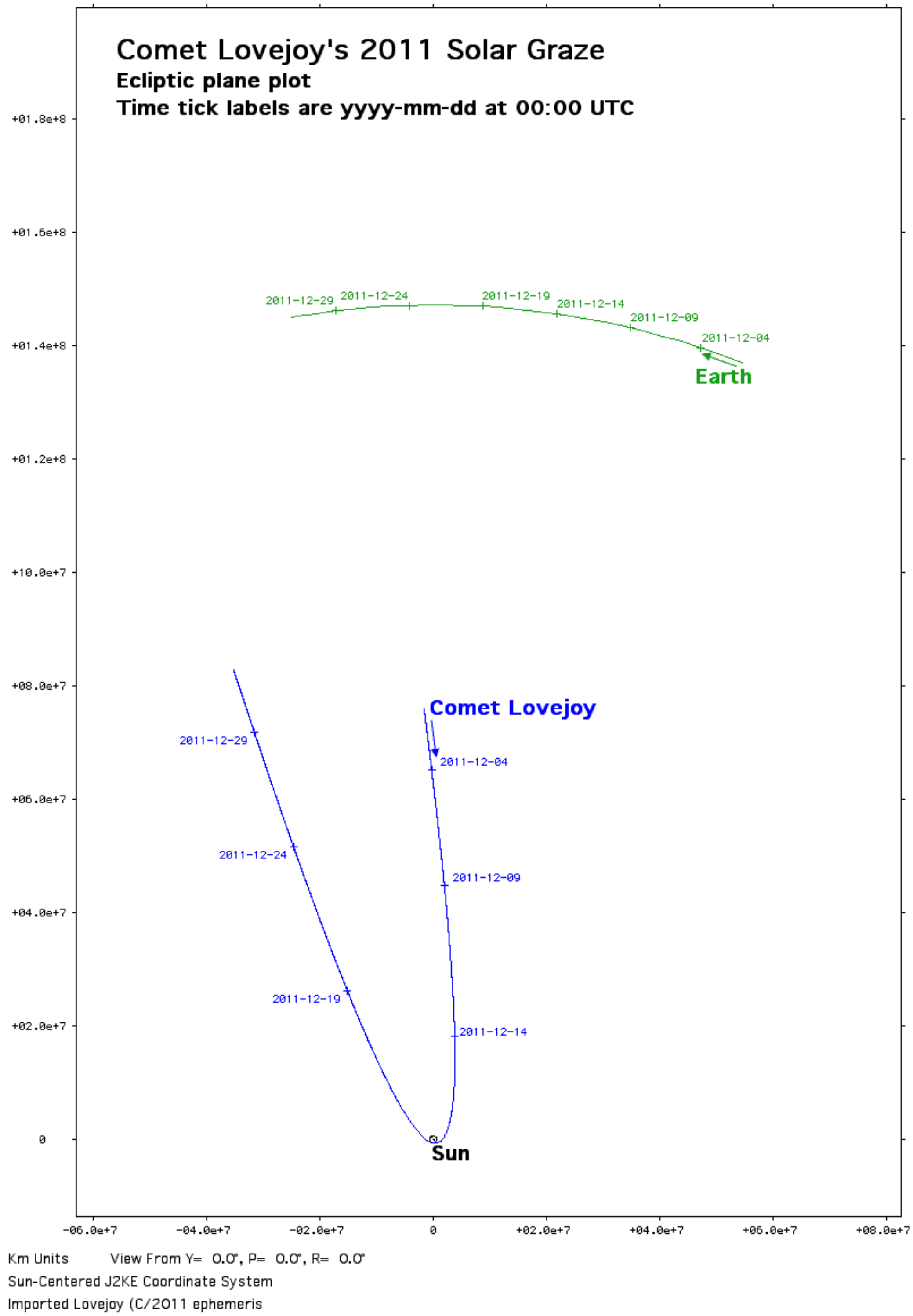


Figure 1. A plot in Earth's Sun-centered orbit plane (the ecliptic) illustrates Comet Lovejoy's grazing flight past the Sun during December 2011. From Earth's perspective, Lovejoy appears to tunnel through the Sun. The comet's orbit period is 314 years, with its maximum solar distance (aphelion) more than 92 times Earth's.

Staying Informed

Editor's note: Daniel Adamo's figures clarify some aspects of comet Lovejoy's close pass by the Sun. He called our attention to this web site,
Comet Lovejoy Survival:
http://sungrazer.nrl.navy.mil/index.php?p=news/birthday_comet
where Karl Battams of the Naval Research Laboratory (NRL) communicates the excitement and surprise of the comet watchers as they monitor results of comet Lovejoy's Sun grazing from several spacecraft observatories.

Right: Image credit: Daniel R. Adamo, Astrodynamics Consultant.

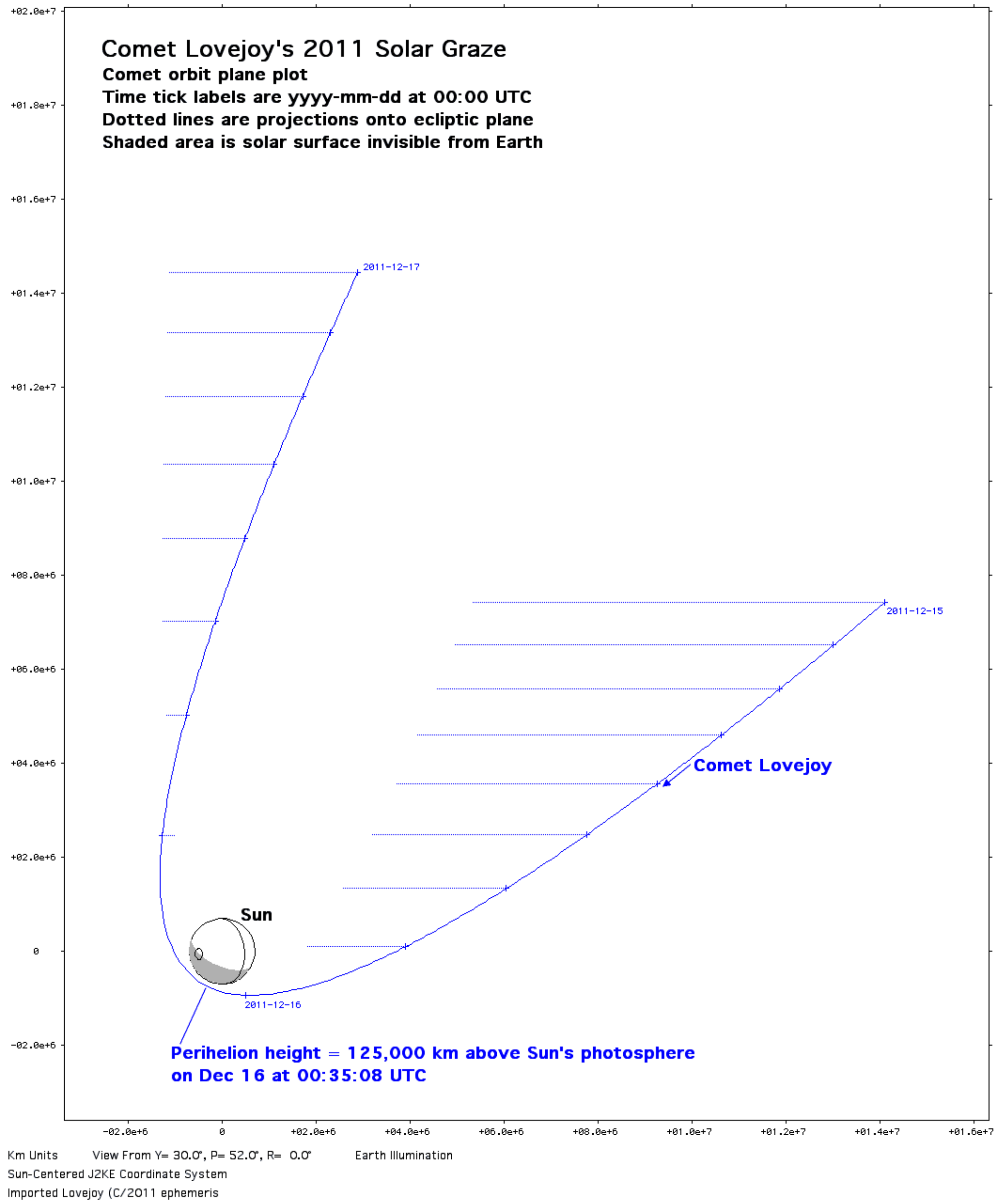


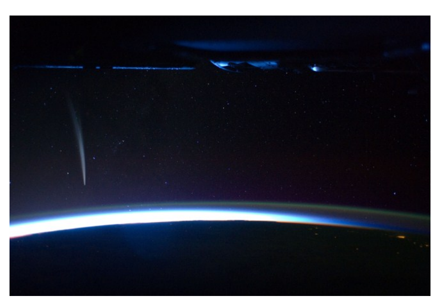
Figure 2. This plot in the plane of Comet Lovejoy's orbit illustrates its Sun-centered motion during a two-day interval containing closest approach (perihelion). The Sun's humanly perceived surface (photosphere) is shaded where it is not observable from Earth's perspective. Dotted projection lines indicate Lovejoy's orbit lies well below the ecliptic plane except for a brief interval from a few minutes before perihelion until a few hours afterward. A collision with Earth is therefore impossible unless this orbit is significantly altered. Comet Lovejoy orbit data are from JPL Solar System Dynamics solution #24.

Editor's note: On Dec. 16, 2011, Sun-grazing comet Lovejoy surprised astronomers by surviving its spectacular pass by the Sun. Its long tail was lost but was expected to grow back, as noted by Karl Battams on the web site noted on the previous page. Comet Lovejoy was already big news and historic because of its survival when, on Dec. 21, 2011, astronaut Dan Burbank took photographs and video like the one shown in the bottom right corner of this page. He was in orbit around the Earth onboard the International Space Station (ISS), and this opportunity was a surprise. The next day, he took photographs like the one below.

Staying Informed

Left: ISS030-E-015472 (22 Dec. 2011) --- Comet Lovejoy is visible near Earth's horizon in this nighttime image photographed by NASA astronaut Dan Burbank, Expedition 30 commander, onboard the International Space Station on Dec. 22, 2011. Image credit: NASA.

Below: ISS030-E-014379 (21 Dec. 2011) --- Comet Lovejoy is visible near Earth's horizon in this nighttime image photographed by NASA astronaut Dan Burbank, Expedition 30 commander, onboard the International Space Station on Dec. 21, 2011. Image credit: NASA.



Calendar

AIAA Houston Section events & other events related to aeronautics & astronautics.
This Jan. / Feb. 2012 issue of Horizons is scheduled to be online by Feb. 29, 2012.
All items are subject to change without notice.

AIAA Houston Section council meetings: for info, email secretary[at]aiaa-houston.org
Time: 5:30 - 6:30 PM usually
Day: First Monday of most months except for holidays.
Location: NASA/JSC Gilruth Center is often used. The room varies.
Monday, March 5, 2012, Monday, April 2, 2012, Monday, May 7, 2012, and Monday, June 4, 2012. The new AIAA year starts July 1, 2012.

Tuesday, March 27, 2012: Dinner meeting.
Speaker: Douglas Terrier, NASA/JSC.
Location: NASA/JSC Gilruth Center
Friday and Saturday, April 6 and 7, 2012: See pages 53 for related deadlines.
AIAA Region IV Student Conference, https://region4.aiaastudentconference.org/
Location: NASA/Johnson Space Center
Saturday, April 7, 2012 Ninth Annual Yuri's Night Houston 5k Fun Run/Walk.
Challenger Seven Memorial Park, 8:00 AM Kids' 1k, 8:15 AM 5k Fun Run/Walk.
www.yurisnighthouston.net, ynh.funrun[at]gmail.com.
Space Day? The Celebration? Please see the web site for details.
Yuri's Night Houston 2012 is an AIAA Houston Section event.
Friday, May 18, 2012: ATS 2012. See page 52.
AIAA Houston Section Annual Technical Symposium (ATS 2012)
June 2012, on a weeknight (Monday - Thursday): Dinner meeting.
Speaker: Norman Chaffee, NASA/JSC retired
Additional speakers include: Guy Thibodaux, NASA/JSC retired, James C. McLane, Jr., NASA/JSC retired.
Location: TBD (possibly the 1940 Air Terminal Museum at Hobby Airport, www.1940airterminal.org)
Celebrating the 50th anniversary of AIAA Houston Section.

AIAA National & International Conferences

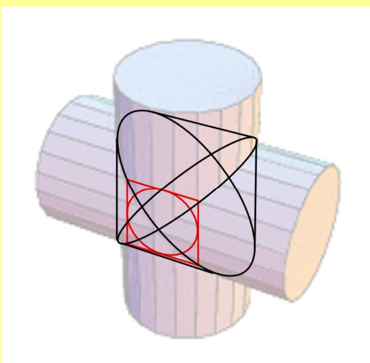
20 - 21 March 2012: Congressional Visits Day
Location: Washington, DC
Venue: Capitol Hill, Type: AIAA Conference
26 - 28 March 2012:
10th U.S. Missile Defense Conference and Exhibit, Type: AIAA Conference
Location: Washington, DC
Venue: Ronald Reagan Building and International Trade Center
23 - 26 April 2012: 53rd AIAA/ASME/ASCE/AHS/ASC Structures, Structural Dynamics and Materials Conference
20th AIAA/ASME/AHS Adaptive Structures Conference
14th AIAA Non-Deterministic Approaches Conference
13th AIAA Gossamer Systems Forum
8th AIAA Multidisciplinary Design Optimization Specialist Conference
Location: Honolulu, Hawaii
Venue: Sheraton Waikiki
9 May 2012: The 2012 Aerospace Spotlight Awards Gala, Washington, DC
22 - 24 May 2012: Global Space Exploration Conference, Washington, DC
7 June 2012: Aerospace Today… and Tomorrow - An Executive Symposium
Location: Williamsburg, Virginia
19 - 21 June 2012: Infotech@Aerospace 2012, Garden Grove, California
25-28 June 2012: AIAA Fluid Dynamics and Co-Located Conferences and Exhibit
Location: New Orleans, Louisiana

Cranium Cruncher

Challenge

DR. STEVEN E. EVERETT

In the last issue, the reader was challenged to compute the volume of a pair of intersecting pipes of radius r and length 4r with only the formulas for the area of a circle and the volume of a sphere, and without using calculus. The volume of this region, called a bicylinder, was known to Archimedes, long before the invention of calculus. It can be derived by first determining the volume of the intersecting space, called a Steinmetz solid, whose edges are shown in black. A representative vertical slice is illustrated by the red square. The ratio of the area of the inscribed circle, also in red, to that of the square is easily shown to be $\pi/4$. It may also be noted that the set of circles which are inscribed in the slices of the Steinmetz solid are the intersections of a sphere with radius r, having a volume of $4/3\ \pi\ r^3$. If we note that the ratio of the areas of the circles to that of the squares is equal to the ratio of the sphere to the Steinmetz solid, its volume can then be computed as $16/3\ r^3$. Since each cylinder has length 4r, their individual volumes are $4\ \pi\ r^3$. Multiplying by two and subtracting the intersecting volume yields a total volume of $(8\ \pi - 16/3)\ r^3$.



This week's puzzle:

A rather less experienced engineer than that in last week's puzzle has been put in charge of connecting the wiring in a new spacecraft. He is presented with a pile of 100 electrical cables, each with a male and a female end, and so he decides to begin connecting the ends of them randomly. He repeats the process until there are no loose ends left. What is the expected value of the number of loops he has created?

Send solutions to steven.e.everett at boeing.com

Section News

The Early Warning Flyer is partially hidden on this page. It is presented in full on page three of our last issue, the November / December 2011 Horizons newsletter: www.aiaa-houston.org.

One keynote speaker is confirmed so far: Mark Geyer, NASA/JSC (Orion MPCV).

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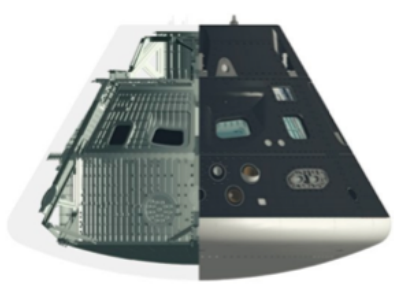
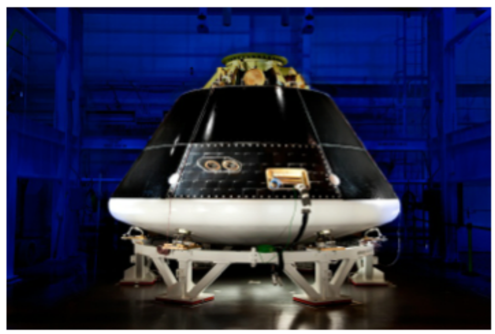
Web site: www.aiaa-houston.org

Call for Abstracts

AIAA Houston Section
Annual Technical Symposium (ATS 2012)
Date: Friday, May 18, 2012
Location: NASA/JSC Gilruth Center

Orion Multi-Purpose Crew Vehicle (MPCV) images courtesy of www.theatlantic.com and www.americaspace.org.

Abstract Submission

Submit abstracts with short author biographies electronically at the AIAA Houston Section web site:

www.aiaa-houston.org

Abstract Guidelines:

- Abstracts should be 250 words or less.
- Sixteen topics are listed for ATS 2012 on the early warning flyer: space exploration, avionics, etc.
- Note the tracking number and password supplied when an abstract has been submitted.
- Submitted abstracts may be updated using the tracking number and password.
- Abstracts will be published. No paper is required.
- Abstracts, Posters, and Presentations must be cleared by authors (not AIAA) for Export Compliance.
- ATS registration is a separate process from the abstract submittal process.
- *Abstracts due Monday, April 30, 2012*
- Authors will be notified on Monday, May 7, 2012 of abstract acceptance.

For more information: ATS General Chair Satya Pilla, vicechair-tech@aiaa-houston.org.

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2012
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Topics

Space Exploration
Astrodynamics
Automation and Robotics
Communication and Tracking
EVA
GN&C
In-Space Imaging
Space Operations
Life Sciences and Human Factors
Propulsion and Power Systems
SR&QA
Systems Engineering
Space Commercialization
Structural Mechanics
Avionics
International Space Activities

during registration

aph projectors available)
kers have the option to use their own laptop.
entations expected at the registration desk.
rship is not required.
D)
ersonnel, and NASA/JSC contractors.

Contact the ATS General Chair for more information: Satya Pilla: vicechair-tech@aiaa-houston.org

Tentative Deadlines

Monday, April 30, 2012	– Abstracts due to planning committee (contact us sooner if possible)
Monday, May 7, 2012	– Abstract authors notified of abstract acceptance
Thursday, May 17, 2012	– Luncheon Reservations (pay at the door on Friday, May 18, 2012)
Friday, May 18, 2012	– Attendee and Speaker Registration Fee Payments (all day, starting at 8:00 AM)

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The American Institute of Aeronautics and Astronautics

Section News

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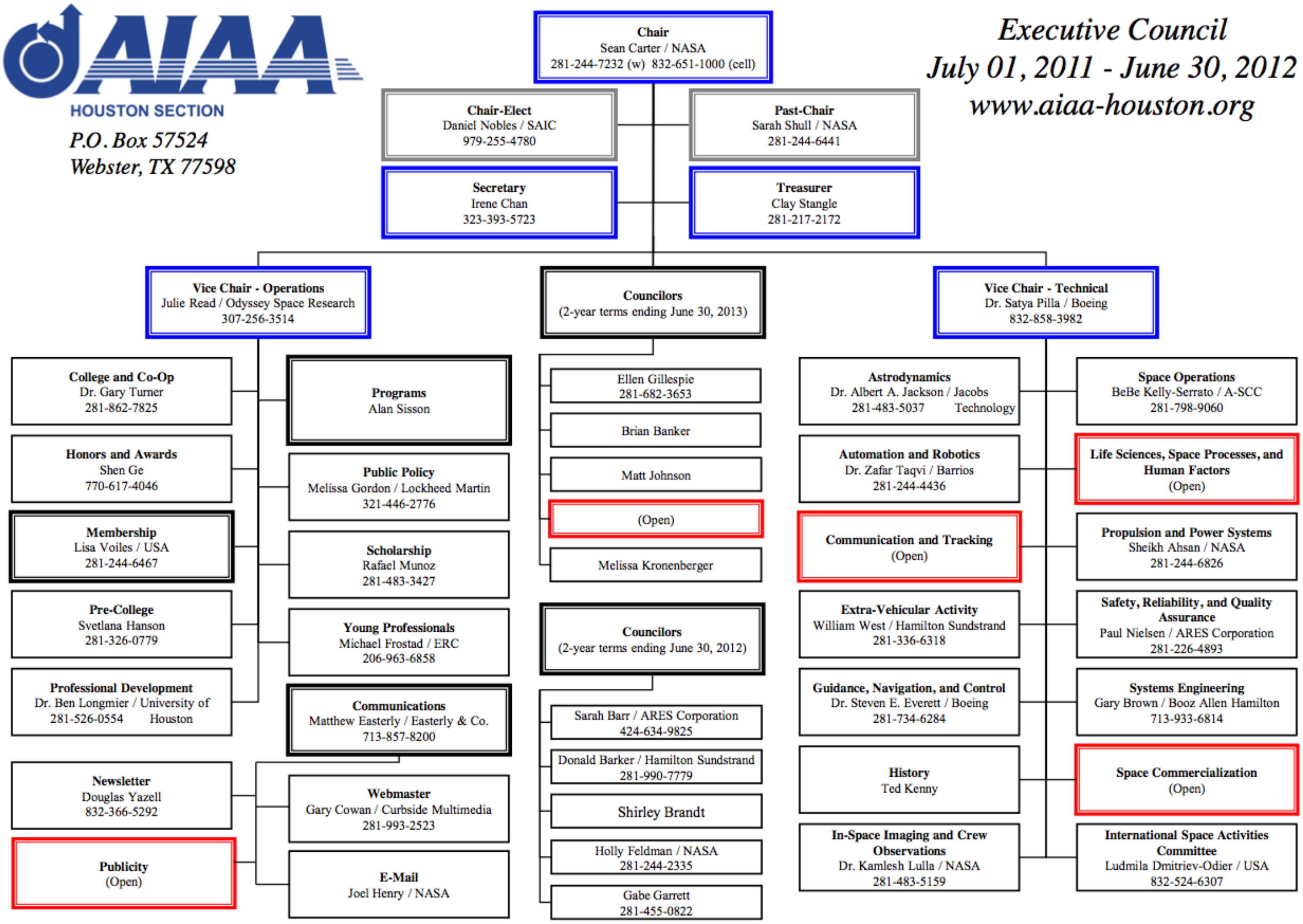
Executive Council
July 01, 2011 - June 30, 2012
www.aiaa-houston.org



Updated November 8, 2011, Executive Council Voting Members (20) are identified by:

AIAA Region IV Student Conference

Friday and Saturday, April 6 - 7, 2012
NASA/Johnson Space Center, Houston, Texas
Hosted by AIAA Houston Section and UT Austin
https://region4.aiaastudentconference.org/

Date	Event
Saturday, January 14, 2012, *12:00am*	Registration Opens
Monday, March 12, 2012, *11:59pm*	Registration Closes
Monday, March 12, 2012, *11:59pm*	Abstracts Due
Wednesday, March 14, 2012, *11:59pm*	Papers Due
Monday, March 19, 2012, *11:59pm*	Cancellation Deadline
Thursday, April 5, 2012, *11:59pm*	Presentations Due
Friday, April 6 - Saturday, April 7, 2012	Conference

Titles of AIAA Conference Papers Authored by AIAA Houston Section Members

COMPILED BY THE EDITOR USING THE AIAA E-LIBRARY, EMAIL EDITOR-IN-CHIEF[AT]AIAA-HOUSTON.ORG

50th AIAA Aerospace Sciences Meeting including the New Horizons Forum and Aerospace Exposition Nashville, Tennessee January 9-12, 2012

Vortex Lift Waverider Configurations
Patrick Rodi Lockheed Martin Corporation, Houston, TX, AIAA-2012-1238

Assessing Uncertainties in Boundary Layer Transition Predictions for HIFiRE-1 at Non-zero Angles of Attack
Lindsay Marek NASA Johnson Space Center, Houston, TX, AIAA-2012-1015

An Investigation of the Relationship Between the Residual Strength of Glass and Pit Diameter After Hypervelocity Impact
Nehemiah Williams University of Tennessee Space Institute, Tullahoma, TN; James McMahon NASA Johnson Space Center, Houston, TX, AIAA-2012-873

Continuing Validation of Computational Fluid Dynamics for Supersonic Retropropulsion
Daniel Schauerhamer Jacobs, Houston, TX; Kerry Trumble NASA Ames Research Center, Moffett Field, CA; William Kleb NASA Langley Research Center, Hampton, VA; Jan-Renee Carlson NASA Langley Research Center, Hampton, VA; Karl Edquist NASA Langley Research Center, Hampton, VA, AIAA-2012-864

Experimental Measurements of Heat Transfer Rates Through a Lunar Regolith Simulant in a Vibro-Fluidized Reactor Oven
Vedha Nayagam NASA Glenn Research Center, Cleveland, OH; Kurt Sacksteder NASA Glenn Research Center, Cleveland, OH; Aaron Paz NASA Johnson Space Center, Houston, TX, AIAA-2012-635

The lagRST Model: a Turbulence Model for Non-Equilibrium Flows
Randolph Lillard NASA Johnson Space Center, Houston, TX; Michael Olsen NASA Ames Research Center, Moffett Field, CA; Brandon Oliver NASA Johnson Space Center, Houston, TX; Gregory Blaisdell Purdue University, West Lafayette, IN; Anastasios Lyrintzis Purdue University, West Lafayette, IN, AIAA-2012-444

(Continued on page 55)

The World's Forum for Aerospace Leadership

(Continued from page 54)

Lock-in of Elastically Mounted Airfoils at High Angles of Attack
Robert Ehrmann Texas A&M University, College Station, TX; Kristina Loftin Texas A&M University, College Station, TX; Shalom Johnson Texas A&M University, College Station, TX; Edward White Texas A&M University, College Station, TX, AIAA-2012-1209

Boundary-Layer Transition on a Flared Cone in the Texas A&M Mach 6 Quiet Tunnel
Jerrod Hofferth Texas A&M University, College Station, TX; William Saric Texas A&M University, College Station, TX, AIAA-2012-923

JoKHeR: NPSE Simulations of Hypersonic Crossflow Instability
Joseph Kuehl Texas A&M University, College Station, TX; Eduardo Perez Texas A&M University, College Station, TX; Helen Reed Texas A&M University, College Station, TX, AIAA-2012-921

A Novel Design of an Exo-Solar Planet Imager
Hyerim Kim Texas A&M University, College Station, TX; Dastan Khussainov Texas A&M University, College Station, TX; Michael Kim Texas A&M University, College Station, TX; James Quinn Texas A&M University, College Station, TX; David Hyland Texas A&M University, College Station, TX, AIAA-2012-879

Repetitively Pulsed Hypersonic Flow Apparatus for Advanced Laser Diagnostic Development
Rodrigo Sanchez-Gonzalez Texas A&M University, College Station, TX; Ravichandra Srinivasan Texas A&M University, College Station, TX; Jerrod Hofferth Texas A&M University, College Station, TX; Doyong Kim Texas A&M University, College Station, TX; Rodney Bowersox Texas A&M University, College Station, TX; Simon North Texas A&M University, College Station, TX, AIAA-2012-733

Freestream Turbulence Measurements in a Continuously Variable Hypersonic Wind Tunnel
Michael Semper Texas A&M University, College Station, TX; Brandon Pruski Texas A&M University, College Station, TX; Rodney Bowersox Texas A&M University, College Station, TX, AIAA-2012-732

Feasibility of One-Dimensional Rotational and Vibrational Raman in High Speed Flames
Alex Bayeh Texas A&M University, College Station, TX; Adonios Karpetis Texas A&M University, College Station, TX, AIAA-2012-613

AggieSat2 Student Satellite Mission
John Graves Texas A&M University, College Station, TX; Joseph Perez Texas A&M University, College Station, TX; Helen Reed Texas A&M University, College Station, TX, AIAA-2012-434

Proper Orthogonal Decomposition Applied to the Reynolds-Averaged Navier--Stokes Equations
Brian Freno Texas A&M University, College Station, TX; Thomas Brenner Texas A&M University, College Station, TX; Paul Cizmas Texas A&M University, College Station, TX, AIAA-2012-314

Modeling and Analysis of Eagle Flight Mechanics from Experimental Flight Data
Steven Shepherd Texas A&M University, College Station, TX; John Valasek Texas A&M University, College Station, TX, AIAA-2012-27

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Above: ISS031-S-002 (14 July 2011) --- Expedition 31 crew members take a break from training at NASA's Johnson Space Center to pose for a crew portrait. Pictured on the front row are Russian cosmonauts Oleg Kononenko (right), commander; and Gennady Padalka, flight engineer. Pictured from the left (back row) are NASA astronaut Joe Acaba, Russian cosmonaut Sergei Revin, European Space Agency astronaut Andre Kuipers and NASA astronaut Don Pettit, all flight engineers. Photo credit: NASA.

ISS031-S-001 (September 2011) --- Thin crescents along the horizons of Earth and its moon depict International Space Station (ISS) Expedition 31. The shape of the patch represents a view of our galaxy. The black background symbolizes the research into dark matter, one of the scientific objectives of Expedition 31. At the heart of the patch are Earth, its moon, Mars, and asteroids, the focus of current and future exploration. The ISS is shown in an orbit around Earth, with a collection of stars for the Expedition 30 and 31 crews. The small stars symbolize the visiting vehicles that will dock with the complex during this expedition. Photo credit: NASA and its International Partners.

AIAA Mission & Vision Statement

The shaping, dynamic force in aerospace - THE forum for innovation, excellence and global leadership. AIAA advances the state of aerospace science, engineering, and technological leadership. Core missions include communications and advocacy, products and programs, membership value, and market and workforce development.

The World's Forum for Aerospace Leadership

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