



TIROS SPACE INFORMATION  
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*First Lunar Outpost*

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The *Tiros Space Information (TSI) - News Bulletin* is published to promote the scientific exploration and commercial application of space through the dissemination of current news and historical facts. In doing so, Tiros Space Information continues the traditions of the Western Australian Branch of the Astronautical Society of Australia (1973-1975) and the Astronautical Society of Western Australia (ASWA) (1975-2006).

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## Calling card...

I have often commented on the low standard of press releases. Press releases are important to historians such as me. They need not give the full story, but they should be sufficient for us to start searching for further information if we desire so.

A recent example of bad press releases concerned AggieSat-4/Bevo-2, described in this News Bulletin. This payload was sent to ISS on Cygnus Orb-4 but information released at the time of the launch on 6 December 2015, did not make any a reference to this payload that was probably hidden in some generic description of cargo. In the past NASA used to prepare detailed cargo manifests for such missions, but they do not seem to do so anymore. Press information released by Orbital-ATK is also pretty useless.

The other recent example of this is the Dragon 2 Propulsive Hover Test of 24 November 2015, details of which did not become evident until about two months later through a message by Mr Elon Musk on social media.

In my opinion social media are not the way to disseminate news like this so, unless Musk wishes to boast that he has so many 'friends' on social media, he should change his dissemination of news to some more conventional communication means and do so timely – not when it pleases him.

Jos Heyman

## Gnangara Tracking Station

After a service of nearly 30 years the 15 meter diameter satellite antenna at the Gnangara Tracking Station in Perth, Western Australia has been retired.

The antenna, which first operated in Canarvon in 1986 in support of ESA's Giotto programme and was later moved to Gnangara in support of other ESA missions, was fitted for reception in both S and X band and transmissions in the S band.

The reason for the retirement is the encroaching outer suburbs of the Perth Metropolitan region which has caused interference with transmissions.

The site was originally owned by the government owned Overseas Telecommunications Commission (OTC), and began operations in November 1986. It is currently operated by Telstra and is also used for international communications.

## Sentinel-2

ESA has ordered two more satellites in the Sentinel-2 series of Earth observation satellites. Satellites in this series provide multi-spectral images in 13 bands with a resolution of 120 m, depending on the band chosen. The first in the series was launched on 23 June 2015. Sentinel-2B is expected to be launched in September 2016 whilst the additional two, Sentinel-2C and -2D will be placed in orbit from 2021 onwards.

## SpaceX Mars mission?

At a recent event Elon Musk, the owner of SpaceX, stated he hopes to develop a spacecraft that will be able to send humans to Mars within a decade. He anticipated a description of the architecture of the spacecraft to be available for the International Astronautical Conference in Mexico in late September.

Musk said space travel to Mars is part of a larger vision of one day establishing a city on the Red Planet.

## JCSat-17

Japan's Sky Perfect JCSat has ordered the JCSat-17 communications satellite from Lockheed Martin. It will be based on the A2100 platform and will be fitted with C and Ku band transponders as well as an S band antenna to ensure communications continuity during disaster relief efforts. Launch is planned for 2019.

## COWVR

The Compact Ocean Wind Vector Radiometer (COWVR) is a proposed US military meteorological satellite to provide ocean surface vector wind and tropical cyclone data. If approved, it could be launched in 2017.

## Satellite Update

### Launches in January 2016

Int.Des.	Name	Launch date	Launch vehicle	Country	Notes
2016 001A	Belintersat-1	15-Jan-2016	CZ 3B/E	Belarus	Communications
2016 002A	Jason-3	17-Jan-2016	Falcon 9 v1.1	USA/Fran.	Earth observation
2016 003A	IRNSS-1E	20-Jan-2016	PSLV XL	India	Navigational
sub-orbital	New Shepard Test-3	22-Jan-2016	New Shepard	USA	Test
2016 004A	Intelsat-29e	27-Jan-2016	Ariane 5ECA	Intelsat	Communications
2016 005A	Eutelsat 9-B	29-Jan-2016	Proton M/Briz M	Eutelsat	Communications
1998 067HP	AggieSat-4/Bevo-2	29-Jan-2016	ISS	USA	Technology

### Other updates

Int. Des.	Name	Notes
1984 079A	Kosmos-1586	Re-entered 6 January 2016
1998 067GV	Centennial-1	Re-entered 6 January 2016
2013 064G	ORSES	Re-entered 3 January 2016
---	Dragon 2 Propulsive Hover Test	Hover test suspended from a crane at McGregor, TX, took place on 24 November 2015.

## Vostochny

The first launch from the Russian Vostochny Cosmodrome in Siberia, is expected to take place in April 2016 using a Soyuz-2.1a launch vehicle. Essentially a test launch, the rocket will carry three satellites:

- Aist-2D, a 531 kg technology satellite developed by TsSKB Progress in partnership with Samara State Aerospace University, to demonstrate a new small spacecraft design. It will be fitted with a high-resolution hyperspectral imaging camera and an innovative radar operating in P-band. In addition there will be instruments that monitor the performance of the satellite itself;
- SamSat 218, a cubesat designed and built by students at Samara State Aerospace as an educational and technology demonstration; and
- Mikhailo Lomonosov, a 450 kg satellite developed by students at Lomonosov Moscow State University that will study high-energy cosmic rays and gamma-ray bursts as well as the Earth's magnetosphere.

Construction of Vostochny started in 2011 to give Russia a launch facility in its own territory, in lieu of Baikonour that, originally within the former USSR, is now in Kazakhstan. Whilst Russia will not abandon Baikonour, Vostochny will be the location where the Angara replacement of the Proton launch vehicle, will be operated from commencing in 2021.

## AggieSat-4/Bevo-2

On 29 January 2016 astronauts on board of ISS deployed the AggieSat-4 satellite through the airlock of the Kibo module, using the robotic arm.



*Astronauts Kelly and Peake move the Aggiesat-4/Bevo-2 deployer into the Kibo module*

AggieSat-4 is part of NASA's Low-Earth Orbiting Navigation Experiment for Spacecraft Testing Autonomous Rendezvous and Docking (LONESTAR)-2 programme and was built by students at the Texas A&M University. With a mass of 55 kg, the satellite will demonstrate three-axis attitude determination and control using a DRAGON GPS unit as well as a camera system to capture visuals of various mission events while in orbit.

It will also release the Bevo-2 satellite and capture this release on video and computed and crosslinked relative navigation solutions through tracking Bevo-2. AggieSat-4 also carried an amateur radio payload.

The Bevo-2 satellite, a 3U cubesat, will be released after one month. Built by students at the University of Texas at Austin, the 4.2 kg satellite carries an amateur radio payload as well as a cold gas thruster module holding 90 grams of Dupont R-236fa refrigerant stored at pressure to be released for maneuvers of the satellite for stationkeeping and rendezvous exercises with AggieSat4.

The AggieSat-4/Bevo-2 combination was sent to ISS on the Cygnus Orb-4 cargo spacecraft that was launched on 6 December 2015.

The LONESTAR-1 mission took place on 30 July 2009 and the Aggiesat-2 and Bevo-1 satellites were then called DRAGONSat-1 and -2. They failed to separate.

Another two LONESTAR missions are planned.

## Cancelled Projects: First Lunar Outpost

By Jos Heyman

If George H. W. Bush's Space Exploration Initiative (SEI) would have been realized, the year 2016 would have seen humans land on Mars.

His ambitious plans were announced on 20 July 1989, the 20<sup>th</sup> anniversary of the Apollo-11 moon landing and included, apart from the Mars landing, a return to the Moon by 2001 as well as Space Station Freedom. To a certain extent this initiative was a follow-on from the 'Ride Report', formally known as 'Leadership and America's Future in Space', a series of recommendations made in August 1987 by a committee chaired by former astronaut Dr. Sally Ride.

Although some studies resulted from the Bush initiative, it was doomed to fail right from the start as it faced a hostile Congress with a Democratic majority. This hostility was not just politically driven, but also financially motivated, as the entire initiative proved to be too expensive. It was therefore no surprise that the next President, Bill Clinton, dumped the initiative when he took up office.

However, SEI, in a roundabout way, spawned the First Lunar Outpost (FLO) plan that was unveiled by NASA in 1992.

FLO was seen as a baseline proposal against which competing proposals and alternative strategies could be benchmarked.

The study had been undertaken by NASA's Office of Exploration and was a departure from earlier post-Apollo plans that had concentrated on re-usability (meaning the use of the Space Shuttle and the proposed Freedom space station) and returning to the concept of expendable hardware.

FLO envisaged four major pieces of hardware:

- a new launch vehicle, referred to as Comet;
- a lander;
- a crew vehicle; and
- a habitat module

### Comet

The Comet heavy lift launch vehicle was intended to have a capability of placing 254.4 tons into low-Earth orbit and 97.6 tons towards the Moon.

The core stage would have been similar to the Saturn V's S-1C stage with five F-1A rocket engines. It would have been flanked by two booster stages, each powered by two F-1A engines. The F-1A was an upgraded version of the F-1 that had been tested in the early 1970s but had never flown.

The second stage would have had six J-2S engines whilst the third stage, also known as the Trans Lunar Injection Stage (TLI), was to have one J-2S engine.

The proposed launch vehicle had a length of 124.4 m and a diameter of 10 m. This diameter would have been the same for all stages, except that the payload fairing would have been slightly larger.



Comet

### Lander

The 14.1 m tall lander would have been identical for both the crew vehicle and the habitat module configuration and would have been powered by four RL-10 rocket engines. It would also have had eight propellant tanks and four landing legs which had a span of 18.8 m when deployed.

The total mass for the lander would have been 93,526 kg.

### Habitat module

The 35.894 kg habitat module was to be based on the standard module design planned for the Freedom Space Station with modifications to allow the use on the lunar surface. It would have been fitted with two large deployable solar panels that would give it an overall width of 41.1 m. To provide power during the 14 day lunar night, it would also have been fitted with regenerative fuel cells.

Apart from providing living space for the crew, the habitat module was seen as a life science and lunar soil analysis laboratory. It was to remain on the surface of the Moon for future missions.



*Habitat module*

### **Crew vehicle**

For crewed flights the lander would have been attached to an Apollo derived crew vehicle for four astronauts. The spacecraft was to be 5% bigger than the Apollo spacecraft and would have been able to carry 200 kg of lunar soil samples on its return flight.

The Earth return propulsion stage would have utilized hypergolic (=self-igniting) propellants rather than oxygen and hydrogen. It would have had three engines.

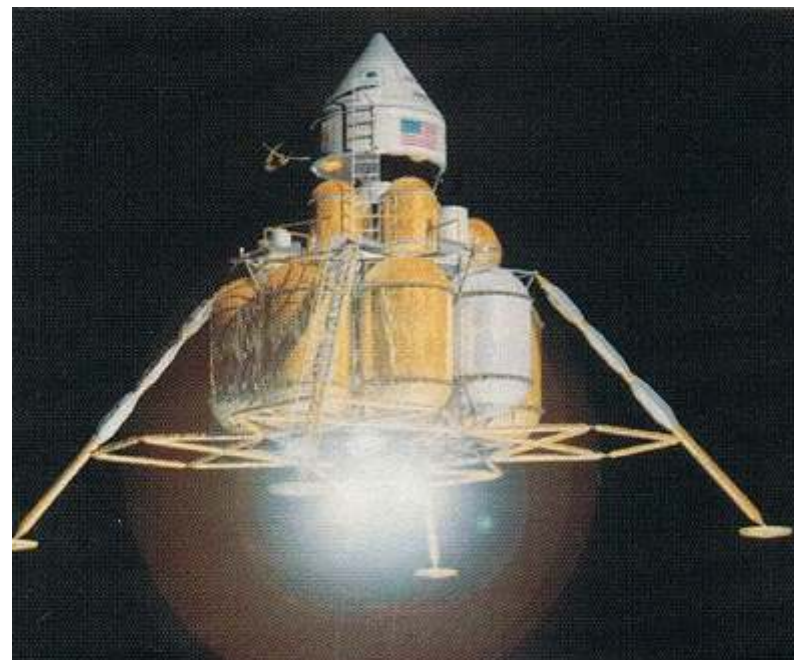
Upon re-entry into the atmosphere the spacecraft would use retrorockets to slow it down, following which parachutes would be deployed. But, unlike Apollo, the spacecraft would touchdown on dry land.

### **Mission profile**

Unlike some contemporary proposals involving Earth orbit assembly, the Comet launch vehicle allowed a direct flight to the Moon where the lander module would be separated from the third stage. It would then fire its RL-10 engine to enter into a lunar parking orbit following which it would land. Two possible landing sites were considered. One was at Mare Smythii whilst the other one was the Aristarchus Plateau.

Prior to the first crewed mission, the habitat module would be sent to the surface of the Moon. This was planned to take place in 2000. After the habitat module was established the first crew would fly to the Moon for a 45 day mission.

Unlike the Apollo program, where the Earth return vehicle was left in lunar orbit, the entire crew vehicle, including the Earth return vehicle, would land on the Moon. This approach was seen to improve mission flexibility and, specifically, the abort profiles. If a problem arose the crew could depart whenever they needed without having to consider limiting orbital mechanics associated with a rendez-vous with an Earth return vehicle in a lunar orbit



*Lunar landing of crew vehicle*

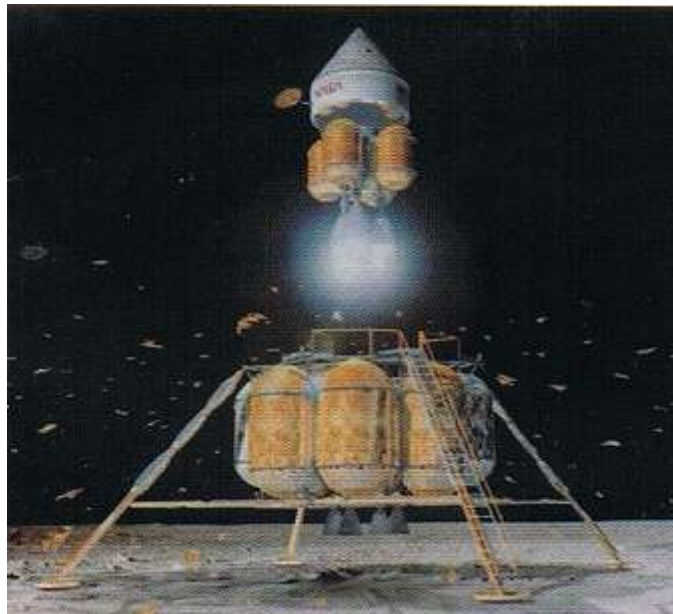
After landing and settling themselves in the habitat module, the crew would start their mission programme, which, on the first mission comprised objectives in astronomy, geophysics, life sciences and space and solar systems physics.

It was planned that each astronaut would make three spacewalks each week, with each spacewalk being a maximum of 8 hours. They would use a lunar rover vehicle to explore an area with a maximum distance of 25 km from the base. This rover could have carried up to four persons.

The crew would also deploy 3,000 kg of scientific equipment, including a geophysical monitoring package, solar system physics package, geophysical package, lunar geologic tool set, lunar transit telescope, small solar telescope, robotic package for the rover, and a life science package. In addition the crew would have demonstrated oxygen extraction techniques from the lunar soil, making bricks from in-situ materials and test pneumatic size sorting methods.



*Habitat module interior*



*Lunar departure*

Future missions would have had different objectives and there was the possibility of adding to the habitat module, eventually leading towards a permanent settlement on the Moon.

## **Cancellation**

According to studies undertaken in 1992, the total cost of the programme, including the first crewed mission, would have been around US\$ 25 billion, to which should be added the cost of NASA overseeing and managing the programme, which would have increased the cost to US\$ 37 billion. Without doubt, had the programme been continued, the cost would have escalated. One of the drawbacks of the FLO programme was also that the key technologies, and in particular the Comet launch vehicle, did not have commercial applications at the completion of the programme, and like Saturn + Apollo, would have been a dead-end project unless there was a long term commitment to missions beyond the Moon, ie to Mars.

When President Bill Clinton took up office in January 1993, FLO was cancelled shortly afterwards.

### *References:*

*Day, Dwayne, A., The Last Lunar Outpost, BIS Spaceflight, Oct 2005, pp. 399-403*

*Wade, Mark, First Lunar Outpost, Encyclopedia Astronautica*

## **Europa Clipper**

NASA has been ordered by the US Congress to add a lander to the Europa Clipper fly-by mission of Jupiter's moon Europa.

As a lander and the associated propellant for a soft landing would probably add another 8000 kg to the 5000 kg estimated for the fly-by spacecraft, this addition to the project means a different approach for the selection of a launch vehicle. So far NASA has considered the use of an Atlas 5 launch vehicle plus planetary fly-bys to reach Europa, or an SLS for direct trajectory to the Jovian system. The latter option would be more expensive but would also allow the spacecraft to reach its destination several years sooner.

With the extra payload mass of the lander, consideration may now have to be given to use two separate Atlas 5 launches. Alternatively, the two payloads could be launched with a single SLS launch but in such a case it would require an inner solar system gravity assists to reach the Jovian system.

The Europa Clipper mission is scheduled for launch in 2022, provided that Congress continues to support its order and provide the funds.

## **Spire, Electron**

The San Francisco based Spire has selected Rocket Lab's Electron small launch vehicle for the deployment of its constellation of more than 100 3U cubesats to collect weather data through a technique known as GPS radio occultation and also provide maritime tracking services

Up to 12 launches are expected to commence late 2016 and continue through 2017. The number of satellites on each of these launches has as yet to be determined.

In the meantime, Rocket Lab has announced that, in addition to the Kaitorete Spit site (refer to TSI News Bulletin, August 2015) it is also developing a launch site on the Mahia Peninsula on New Zealand's North Island.

## QB50

The QB50 project has switched launch vehicles from a Brazilian-Ukrainian Tsyklon 4 rocket that was to be launched from Alcantara in Brazil, to a combination of deployment through the NanoRacks facility on board of ISS and a Dnepr 1 launch vehicle.

The move was forced upon the QB50 project managers due to the ongoing delays with the proposal to launch Tsyklon 4 rockets from Alcantara, something that looks more and more likely not to ever happen.

It has been stated that 40 satellites in the programme will be deployed from ISS through the NanoRacks facility whilst the remaining 10 will be launched by a Dnepr 1. This essentially means that the cubesats will be deployed/launched over an extended period of time during 2016 as the NanoRacks facility can handle only six 1U cubesat or combinations thereof, at a time. Most of the QB50 satellites are 3U cubesats.

The following list from the QB50 website, last updated on 1 April 2015, details 49 cubesats that will participate in the programme.

Code	Country	University/Institute	Name
AT03	Austria	U of App. Sci., Wiener Neustadt	Pegasus
AU01	Australia	The University of Adelaide	SUSat
AU02	Australia	University of New South Wales	UNSW-EC0
AU03	Australia	University of Sydney	i-INSPIRE 2
AZ01	South Africa	Stellenbosch University	ZA-AeroSat
BE05	Belgium	von Karman Institute	QARMAN
BR01	Brazil	Instituto Federal Fluminense	14-BISAT
CA01	Canada	York University, Toronto	YUend-QB50
CA03	Canada	University of Alberta	ExAlta 1
CN01	China	Beihang University	BUSAT 1
CN02	China	Harbin Institute of Technology	LilacSat 1
CN03	China	Nanjing University of Science and Technology	NJUST 1
CN04	China	Northwestern Polytechnic University	Aoxiang 1
CN05	China	Zhejiang University	ZJU CubeSat
CN06	China	National University of Defense Technology	NUDTSat
CN07	China	ShanghaiTech University	STU 1
CZ02	Czech Republic	VZLU	VZLUsat 1
DE04	Germany	FH Aachen, University of Applied Science	DragSail-CubeSat
ES01	Spain	Universidad Politécnica de Madrid	QBITO
FI01	Finland	Aalto University	Aalto 2
FR01	France	École Polytechnique	X-CubeSat
FR02	France	Institut Supérieur de l'Aéronautique et de l'Espace (ISAE)	EntrySat
FR03	France	Institut Supérieur Des Sciences Et Technique (INSSET)	SAT JP2
FR04	France	UPEC	OGMS-SA
FR05	France	MinesParisTech	SpaceCube
GB03	United Kingdom	MSSL, University College London	UCLSat
GB06	United Kingdom	University of Surrey	InflateSail
GR01	Greece	Democritus University of Thrace / Space Research Lab	DUTH
GR02	Greece	University of Patras	UPSat

IL01	Israel	Space Laboratory of the Herzliya Science Center	Hoopoe
IN01	India	Anna University	ANUSAT 2
IT02	Italy	University of Rome "LA SAPIENZA"	URSA MAIOR
KR01	South Korea	Korea Advanced Institute of Science and Technology	LINK
KR02	South Korea	Seoul National University	SNUSAT 1
LT01	Lithuania	Vilnius University	LituanicaSAT 2
NL01	The Netherlands	Delft University of Technology	DELFFI 1
NL02	The Netherlands	Delft University of Technology	DELFFI 2
PT01	Portugal	University of Porto	GAMASAT
RO01	Romania	Institute of Space Science and the Romanian Space Agency Research Center	RoBiSAT 1
RO02	Romania	Institute of Space Science and the Romanian Space Agency Research Center	RoBiSAT 2
RU01	Russia	Samara State Aerospace University	SamSat
TR01	Turkey	Istanbul Technical University / Air Force Academy	BeEagleSat
TR02	Turkey	HAVELSAN	Havelsat
TW01	Taiwan	National Chung Kung University	PHOENIX
UA01	Ukraine	National Technical University of Ukraine	KPI-SAU 1
US01	USA	University of Colorado Boulder	QBUS 1
US02	USA	University of Michigan	QBUS 2
US03	USA	Stanford University	QBUS 3
US04	USA	Inter-America University Puerto Rico	QBUS 4

## USAF new launch system

The US Air Force has submitted a 2017 budget requests for the development of a new launch system that would end its reliance on the Atlas 5 launch vehicle that is powered by Russian rocket engines. If granted, development would take place over the 2017/2020 period.

## E-SBIRS, E-AEHF

The Air Force's 2017 budget request also included plans for follow-ups to the current SBIRS missile warning constellation and the AEHF communications satellites. Identified as Evolved-SBIRS and Evolved-AEHF, these programmes would respectively start in 2018 and 2017 and extend through 2021.

In both programmes the current generation of satellites have been launched with any remaining satellites already in production.

There is no indication as to the number of satellites in each of these new programmes or when a first launch date is expected.

## SLS EM-1 and -2

NASA has announced that 13 cubesats will be placed in orbit with the first launch of the Space Launch System (SLS) expected to take place in 2018. The flight, to be known as Exploration Mission (EM)-1 will first of all demonstrate the performance of the launch vehicle and will place an uncrewed Orion spacecraft into a circumlunar trajectory for seven to ten days ending in a high speed entry to test Orion's thermal protection system.

The 13 cubesat will be deployed after the separation of the Orion spacecraft, using a spring mechanism from dispensers on the Orion stage adapter.

Details of seven of the cubesats were recently published. They are:

1. CubeSat to study Solar Particles (CuSP) to measure particles and magnetic fields in space, and further understand the particles' roles in geothermal storms. The 6U cubesat, developed by the Southwest Research Institute in San Antonio, Texas and NASA, will be placed in an orbit around the Sun. It will carry three instruments:
  - the Suprathermal Ion Spectrograph (SIS) to detect and characterize low-energy solar energetic particles;
  - the Miniaturized Electron and Proton Telescope (MERIT) to provide counts of high-energy solar energetic particles; and
  - the Vector Helium Magnetometer (VHM) to measure the strength and direction of magnetic fields.

CuSP was reconfigured from the CubeSat to study Solar Particles over the Poles (CuSPP) that was to perform similar investigations from a low-Earth orbit, studying solar particles near Earth's poles.

2. LunaH-Map, a 6U cubesat that will be placed in a 5 to 12 km polar orbit around the Moon to map hydrogen that exists within craters, on the plains and in other permanently shadowed regions at the Moon's south pole. The satellite is being developed by the Arizona State University at Tempe. The programme calls for 141 orbits over a period of 60 days during which scientific data will be collected. The main instrument is a neutron detector designed to sense the presence of hydrogen by measuring the energies of neutrons that have interacted with and subsequently leaked back out of the material in the top meter of the lunar surface.
3. Skyfire, a 6U cubesat designed by Lockheed Martin Space Systems to perform a flyby of the Moon and collect infrared sensor data to enhance knowledge of the lunar surface.
4. Lunar IceCube, a 6U cubesat designed by Morehead State University to search for water ice and other resources at a low orbit of only 40 km above the surface of the Moon. The satellite will be fitted with the Broadband InfraRed Compact High Resolution Explorer Spectrometer (BIRCHES). It will also carry a Busek RF Ion BIT-3 electric-propulsion system.
5. Near Earth Asteroid (NEA) Scout, a 6U cubesat built by NASA's Jet Propulsion Laboratory (JPL), to perform reconnaissance of asteroid 1991VG, take pictures and observe its position in space. Should the launch date slip beyond 2018, another target could be selected. Cold gas will provide the initial propulsive maneuvers, but the NEA Scout's solar sail will provide and efficient transit to the target asteroid during an approximate two-year cruise.
6. BioSentinel, a 6U cubesat that will use the budding yeast *S. cerevisiae* to detect and measure double strand breaks (DSBs) that occur in response to deep space radiation and study its impact on living organisms over long durations in deep space. The activity of the yeast cells will be measured using a 3-color LED detection system and the metabolic indicator dye alamarBlue. BioSentinel will be placed in a heliocentric orbit and its data will

be compared with similar experiments conducted on the International Space Station and two similar experiments on Earth. The experiments will be conducted by various NASA centres as well as the Loma Linda University Medical Center and the University of Saskatchewan, Canada.

7. Lunar Flashlight, a 6U cubesat that will search for ice deposits and identify locations where resources may be extracted from the lunar surface. Operating from a lunar polar orbit, the satellite will be fitted with imaging spectrometers.

The remaining six cubesats have yet to be chosen but three will come from the NASA Cube Quest Challenge contest whilst the final three cubesats will come from international partners.



*LunaH-Map*

Meanwhile, meddling by Congress has forced NASA to stop working on human-rating the initial upper stage for the Space Launch System (SLS).

Originally NASA intended to use the human rated Exploration Upper Stage (EUS) on all SLS flights but lower funding level delayed the date that the EUS would be available. To replace it on the first flight of SLS, EM-1, NASA developed the Interim Cryogenic Propulsion Stage (ICPS), an upper stage derived from the Delta 4's upper stage. This stage is not human rated but, since EM-1 will not carry a crew that did not pose a problem.

As the EUS is further delayed and might not be available in time NASA considered human rating the ICPS for the crewed EM-2 flight.

It now seems Congress wants to force NASA to use EUS for the EM-2 flight, meaning that there may be further delays.

## PTD cubesats

As part of the Pathfinder Technology Demonstrator (PTD) project, NASA has requested bids for the delivery of five 6U cubesat platforms. One third of the volume of each of these is expected to be used by NASA technology experiments, implying the remainder will be available for others. The first flight is expected towards the end of 2017.



## Astro-H, ChubuSat-2 and -3, Horyu-4

On 17 February 2016 an H 2A-202 launch vehicle from Tanegashima, placed the Japanese Astro-H and three smaller satellites, in orbit.

Previously known as New exploration X-Ray Telescope (NeXT) and also known as Hitomi, Astro-H is a space telescope to enable high sensitivity observations of celestial sources across a wide energy range, from X-rays to gamma-rays, bands presenting considerable technical challenges. In cooperation with institutions in the USA, Canada and Europe, the mission will explore the structure and evolution of universe through imaging and spectroscopic observation.

The 2400 kg spacecraft is fitted with:

1. the hard X-ray imaging system consisting of two identical mirror-detector instruments, the Hard X-ray Telescope (HXT), which had conical-foil mirrors with graded multilayer reflecting surfaces, and the Hard X-ray Imager (HXI), consisting of four-layers of 0.5 mm thick Double-sided Silicon Strip Detectors (DSSD) and one layer of 0.5—1 mm thick CdTe imaging detector to observe the behavior of soft and hard X-ray photons;
2. the Soft X-ray Spectrometer (SXS) consisting of the Soft X-ray Telescope (SXT-S), the X-ray Calorimeter Spectrometer (XCS) and the cooling system;
3. the Soft Gamma-ray Detector (SGD), a non-focusing soft gamma-ray detector with a 10—600 keV energy range and sensitivity at 300keV;
4. the soft X-ray imaging system consisting of the Soft X-ray Telescope (SXT-I), an imaging mirror and the Soft X-ray Imager (SXI), a CCD camera; and
5. the Canadian Astro-H Metrology System (CAMS).

The three smaller satellites were carried on the Second Stage Adapter ring.



*Secondary payload*

ChubuSat-2, also known as Kinshachi-2, is a 50 kg satellite developed by the Nagoya and Daido Universities and several aerospace companies located in the Chubu region of Japan.

The satellite is fitted with a radiation detector system to examine background radiation from the sun and Earth that could add noise to measurements by Astro-H.

ChubuSat-3, also known as Kinshachi-3, is a 52 kg satellite developed by the Nagoya and Daido Universities and several aerospace companies located in the Chubu region of Japan.

Using the same platform as used for ChubuSat-2, this satellite carries a camera with a resolution of 10 m, to track the retreat of glaciers and shoreline changes to help study global warming as well as detecting space debris. In addition it carries a receiver for the Automatic Information System (AIS) to pick up positional and other information from ships at sea, and an instrument to relay messages between radio amateurs.

Horyu-4, also known as Arc Event Generator and Investigation Satellite (AEGIS), is a 10 kg technology demonstration satellite built by the Kyushu Institute of Technology.

The primary objective is the demonstration of High-Voltage Solar Arrays and associated plasma mitigation techniques. Other instruments carried by the satellite are:

1. an onboard oscilloscope and an arc vision camera to acquire the current waveform and images of arcing phenomena occurring on the solar arrays;
2. a power-system experiment to evaluate the degradation of filmed and coated triple-junction solar cells;
3. Double Langmuir probes to measure the density and temperature of the plasma the satellite flies through;
4. a Vacuum Arc Thruster interfacing with the 300-Volt solar array to complete a demonstration of a trigger-less vacuum arc thruster;
5. an Electron-Emitting Film consisting of a 20-micrometer fluoro-polymer insulation film applied to the high-voltage solar cells to avoid an excessive surface charging on the satellite;
6. the Secret Ink material science experiment to monitor several different polymer materials over an extended period of time for an assessment of their degradation caused by atomic oxygen;
7. the Photoelectron Current Measurement for the generation of electrical spectra on a metal and isolator when illuminated by the sun;
8. a CMOS camera to deliver color photos of Earth to be used in space awareness campaigns and education; and
9. Digi-Singer, an amateur radio payload that can be used by radio operators to upload songs to the satellite which can be sent back using the UHF frequency.

A payload of 8 3U cubesats for commercial purposes, provided through Spaceflight Inc. and Japan Manned Space Systems Corporation (JAMSS), was deleted from the launch because they were not ready. They were to be deployed using the Sherpa space tug. Instead a mass simulator was carried.