Space Technology 5—Technology Validation Update

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Abstract—The Space Technology 5 (ST5) Project, part of NASA's New Millennium Program, will consist of a constellation of three micro-satellites. The validation objectives are to demonstrate the research-quality science capability of the ST5 spacecraft; to operate the three spacecraft as a constellation; and to design, develop, test and flight-validate three capable micro-satellites with new technologies. The project team has made significant progress in the past year in building and testing the ground system and flight hardware. Through component-level testing and spacecraft integration and test, many components have been demonstrated on the ground to begin achieving the validation objectives. We are on target for our February 28, 2006 launch date. A three-month flight demonstration phase is planned, during which we will complete the flight validation objectives.

This paper describes the validation strategy for science capability, constellation operations, and spacecraft and component technologies, as well as progress made to date.[1,2]

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1. INTRODUCTION

Mission Overview

The Space Technology 5 (ST5) Project is part of NASA's New Millennium Program. ST5 will consist of a constellation of three micro-satellites, each approximately 25 kg. The validation objectives are to demonstrate the research-quality science capability of the ST5 spacecraft; to operate the three spacecraft as a constellation; and to design, develop, test and flight-validate three capable micro-satellites with new technologies. The new technologies to be flight validated include the spacecraft itself, Miniature Communication Transponder, Cold Gas Micro-Thruster, Variable Emittance Coatings (VEC), Complementary Metal Oxide Semiconductor Ultra Low Power Radiation Tolerant (CULPRiT) chip, and low voltage power subsystem. In addition, we will demonstrate a number of derived technologies included in the ST5 design: miniature magnetometer, miniature spinning sun sensor, spacecraft deployment mechanism, magnetometer deployment boom, nutation damper, and X-band antenna. The project team has made significant progress in the past year in building and testing the ground system and flight hardware. Through component-level testing and spacecraft integration and test, many components have been demonstrated on the ground to begin achieving the validation objectives. A three-month flight demonstration phase is planned. During this period, we will complete the flight validation objectives. The mission could potentially be extended beyond the 90-day period if funding is available.

Constellation Operations

The ST5 ground system was developed to validate a rapid assembly method for ground components and to validate an autonomous ground systems operations concept. In general, ground system automation components will allow the operations staff to plan weekly and daily operations for all three vehicles, while managing highly constrained on-board resources such as the data recorder and power subsystems, with minimal effort.

Science Validation

The ST5 Science Validation Team plans to validate the three primary areas critical to future magnetospheric constellations: formation flying, micro-satellite suitability as a platform for making scientific measurements, and the autonomous response of the micro-satellites to science events. They will synthesize higher order physical quantities from the collective measurements made by the individual spacecraft. The ST5 spacecraft will take magnetometer measurements over the Earth's auroral ovals, annular regions a few degrees of latitude in width, that encircle the north and south magnetic poles (see Figure 1). When a spacecraft encounters a region of interest (i.e. it encounters a higher magnetic field), it will autonomously change to a higher data rate and resolution. The planned 300 x 4500 km high inclination, sun-synchronous orbit will result in the ST5 spacecraft passing over the Earth's auroral zones 4 times per orbit. The spacecraft will be positioned into two different constellation formations during the course of the 90-day mission.

[2] IEEEAC paper #1521, Version 4, Updated December 29, 2005

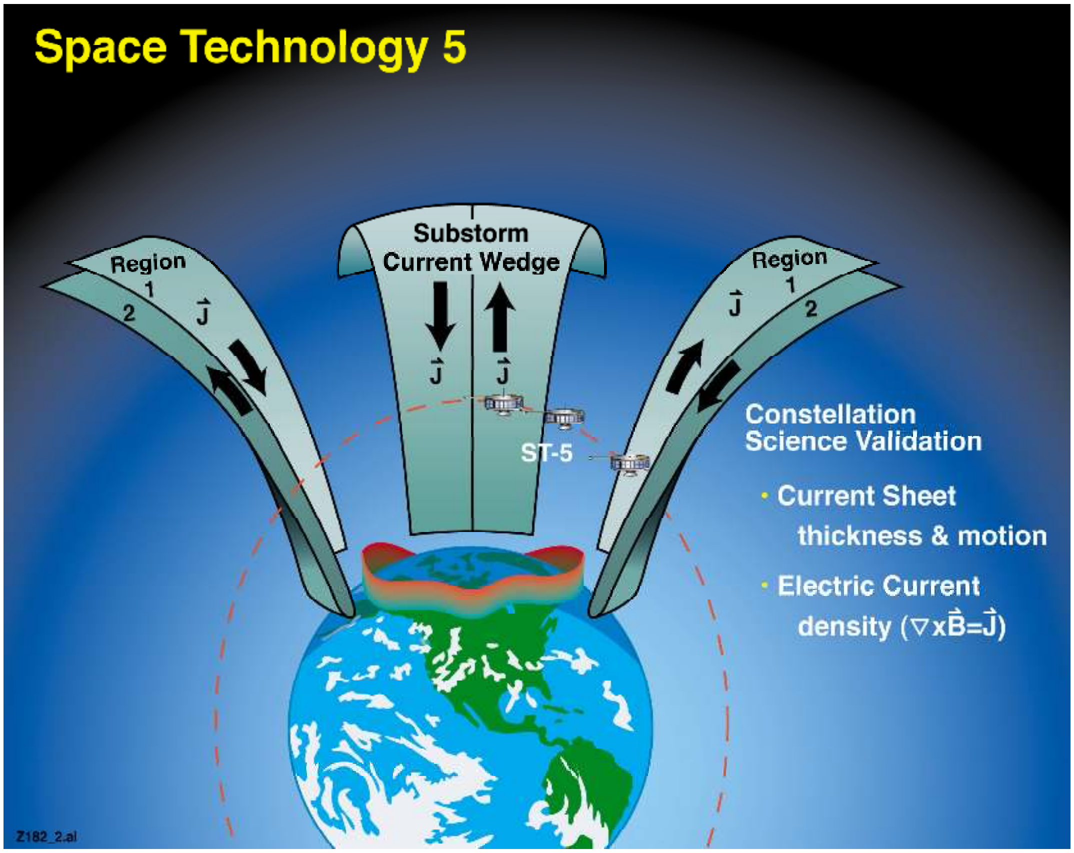


Figure 1, ST5 Science Validation Concept

Spacecraft Overview

ST5's spacecraft bus is developed in-house at Goddard Space Flight Center. Some components are developed in-house, and others by university and industry partners. The ST5 spacecraft, shown in **Figure 2** is octagonal, with body-mounted solar arrays. The top and bottom decks are removable, and a central "card cage" houses the Command and Data Handling (C&DH) and Power System Electronics cards. The spacecraft is spin-stabilized, with a passive nutation damper. The spacecraft thermal control is also passive. In order to reduce interference with the on-board magnetometer, strict magnetic cleanliness requirements were imposed on the spacecraft design.

ST5 includes a miniature fluxgate magnetometer, which produces high-resolution three-axis magnetic measurements. ST5's flight software is capable of detecting science events of interest, i.e. when the rate of change of the ambient magnetic field increases beyond a given threshold. When this occurs, the spacecraft changes the science data collection mode to a higher rate. The magnetometer is required to provide magnetometer measurement data with a resolution of less than 2.0 nano Tesla, an absolute accuracy of better then 0.1 percent, and noise less than 2.0 nano Tesla at a frequency of 1 Hz within a bandwidth of 0.5 Hz.

ST5's C&DH provides the sophisticated command and data handling functionality found on larger spacecraft, but in a much smaller package. It coordinates all communications between components on the spacecraft as well as space-to-ground. The C&DH is a single double-sided board that consumes less than 4W of power.

The C&DH card houses the new technology CULPRiT logic. It was developed to operate at low voltage (0.5V supply voltage), while being radiation tolerant. For ST5, CULPRiT technology is being used to implement a Reed-Solomon encoder. Future space missions may be able to benefit from reductions in overall electronics power dissipation of one to two orders of magnitude with widespread use of CULPRiT.

A low voltage power system helps ST5 achieve its size and weight requirements. A triple-junction solar array, composed of 8 body-mounted panels, provides approximately 20-25W of power at approximately 9 - 10V. Lithium Ion batteries provide energy storage of ~ 9 Ah. Both the solar array and battery are controlled by a single Power System Electronics (PSE) board. In addition to providing power to all spacecraft components, the power system provides contingency recovery for over-current, over-voltage, and low battery charge conditions. The nominal unregulated spacecraft bus voltage is 8.4V maximum, and (as the battery state of charge decreases) can range down to 6.5V before automatic load-shedding occurs. The PSE supplies both unregulated and regulated 5V to the various onboard subsystems.

ST5 is spin stabilized. A passive damper controls any nutation of the spin axis that might occur due to initial deployment, on-orbit maneuvers, or dynamic imbalance. The damper is a welded titanium unit without a bellows, fully filled with silicone fluid at a maximum design pressure of 10,000 psi.

ST5 communicates with ground stations via an X-band uplink at 1 kbps and downlink at 1 kbps, 100 kbps, or 200 kbps. One of the new technology components is a miniature transponder that offers a substantial decrease in weight, power, and volume over current operational systems. The required performance is a bit error rate of less than 1x10-5 for each downlink pass. The transponder is used in conjunction with a high power amplifier, diplexer, band pass filter and two X-band antennas. The communications system is compatible with the Deep Space Network, the Ground Network, or small aperture off-the-shelf antennas. Two different types of antennas are being developed for ST5: a quadrifilar helix antenna, and a new technology "evolved" antenna designed with genetic algorithms. One antenna is mounted on each deck (top and bottom) of the ST5 spacecraft. The antennas are enclosed in radomes, which protect them electrically and mechanically.

A single new technology cold-gas micro-thruster provides all ST5 orbit and attitude maneuver capability. The required performance of the micro-thruster is specific impulse greater than 60 sec, and thrust greater than 2.1 Newton at 2000 psi. The propulsion system also includes a lightweight composite tank, a fill-and-drain valve, an in-line filter and a pressure transducer. Thruster Control Electronics (TCE) and Pressure Transducer Electronics (PTE) are used to control the system. Hardware safeguards ensure that the latching thruster valve cannot be opened unless there is sufficient stored energy in the TCE to close the valve.

A miniature sun sensor is used to measure the elevation angle of the sun with respect to the ST5 spin axis. The spacecraft is capable of autonomously repositioning itself to within 10 degrees of the sun line to ensure adequate sunlight on the solar arrays.

The VECs are radiators with switchable emittance states to vary the amount of heat that they radiate to space. The required performance of the VEC is a range of emissivity variation greater than 0.6. Future space missions may be able to efficiently adapt to wide ranging thermal conditions with radiators based on these technologies. The Micro Electro-Mechanical Systems (MEMS) VEC consists of multi-layered silicon shutters that open and close to vary their emittance. The Electro-Static Radiator (ESR) is a thermal control film that varies its radiation by switching heat transfer mechanisms between two plates internally by the use of an electrostatic field. When the plates are in contact, the mechanism between them is conduction and the ESR is in a high-emittance state; when the plates are separated, the mechanism is radiation between them and the ESR is in a low emittance state. ST5 can accommodate two VECs per spacecraft—one each on the top and bottom decks. Due to the technology development schedule, ESR VECs will be flown on the second and third spacecraft, and MEMS VEC on the third spacecraft only.

Pegasus Support Structure

For the Pegasus launch, GSFC developed a Pegasus Support Structure (PSS) to be mounted to the Pegasus XL launch vehicle. It holds the three spacecraft in a stacked configuration. A deployment mechanism releases each spacecraft and imparts an initial spin rate and linear velocity, resulting in an ~20 rpm rotation after the magnetometer boom is deployed.

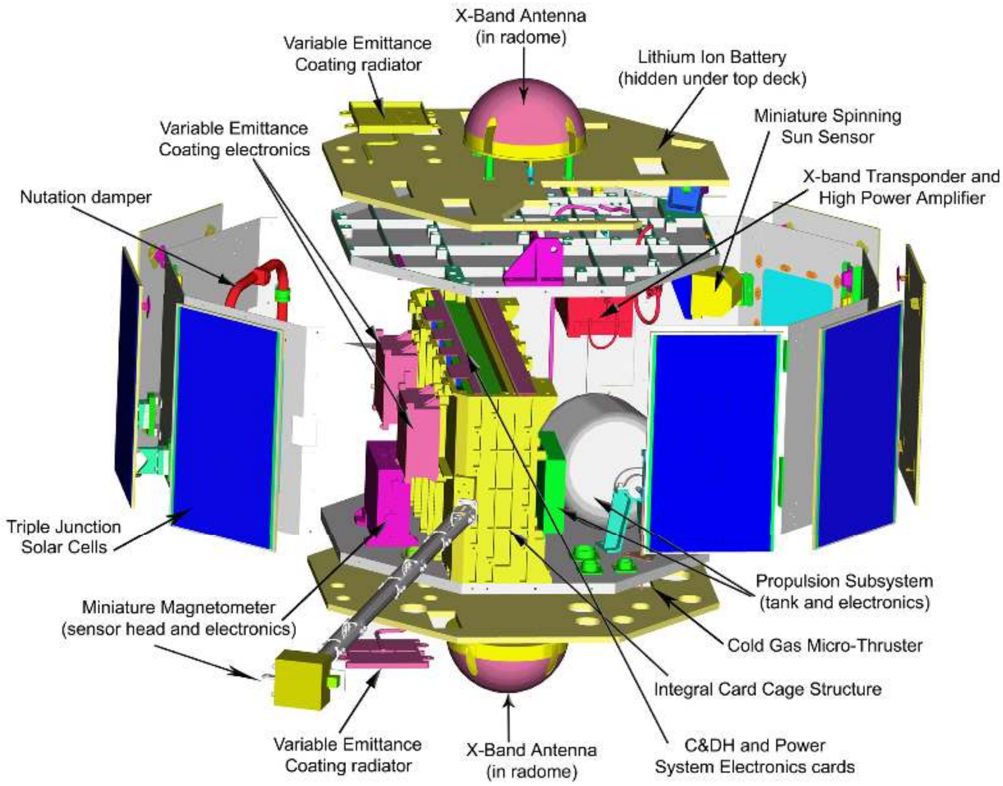


Figure 2, ST5 Spacecraft Components

2. VALIDATION STRATEGY AND PROGRESS

Overview

The component technologies and the spacecraft itself are ground tested using a combination of component-level and system-level testing for the flight hardware in all relevant environments. This testing will generally advance the technologies to New Millennium Program's Technology Readiness Level (TRL) 6, "system/subsystem model or prototype demonstration in a relevant environment (ground or space)."

All mission-level requirements are tracked at the system level by project system engineering personnel. Subsystem-level verification is delegated to Product Design Leads for each subsystem and component. Components and subsystems are delivered to Spacecraft System-level Integration and Test, where they are integrated onto the spacecraft.

Integration and Test and Mission Operations personnel conduct system-level verification. As far as possible, we "test as we fly," using scripts and procedures that transfer from Integration and Test to Mission Operations. The Mission Operations Center and Integration and Test teams use the same ground support hardware (Front End Data System and Advanced System for Integration and Spacecraft Test (ASIST)) for testing. Mission Simulations test the spacecraft, ground system and operations from end-to-end.

Constellation Operations

Ground system capabilities have been delivered, and we are conducting mission simulations, including our automated constellation operations capabilities. We have conducted 6-day and 3-day 24-hour per day simulations using all three flight spacecraft simultaneously, with participation from operations and subsystem personnel. These simulation included constellation and attitude maneuvers as well as science and technology demonstration tests. This allowed us to get a good idea of how the automation capabilities really work, and what fixes are needed before launch. Another 1-day simulation is planned with the flight spacecraft at the launch site.

Science Validation

Prior to the launch of the ST5 spacecraft, the main task for the ST5 science team is to develop the software package for magnetometer data processing. ST5 is spin-stabilized; and the spin axis of each spacecraft maintains a constant inertial orientation. The triaxial magnetometer is mounted to the boom in such a way that one of the axes is approximately along the spin axis and the other two axes are close to the spin plane. The raw counts of the magnetometer data are collected in the frame which spins with the spacecraft. The data processing software transforms the magnetometer raw counts from the spinning frame into the vector magnetic field strength in a fixed inertial coordinate system as well as various geophysical coordinate systems, the so-called "de-spun software". To do so, we need accurate knowledge of the magnetometer sensor characteristics, including the offsets, the gain factors and the pointing direction of the three sensor axes (both relative to each other and to the spacecraft axes). This knowledge is obtained in three ways: (1) pre-flight ground calibrations in the GSFC Magnetic Coil Test Facility, (2) in-flight calibrations based upon the analysis of the spinning data, and (3) post-flight calibrations against the International Geomagnetic Reference Field model of the Earth's magnetic field.

We performed the ground-calibration of the magnetometer sensors in GSFC's magnetic coil facility prior to their integration into the spacecraft. After the integration, we also performed the spacecraft level magnetic test that includes spacecraft magnetic mappings and magnetometer sensor calibrations in the magnetic coil facility. In parallel, we have finished the software module for in-flight data calibrations and validated the software using magnetometer data from previous spinning spacecraft. Currently, we are working on the software module which performs the coordinate transformation among various inertial coordinate systems and tracing the ST5 spacecraft to their ionospheric footprints along the Earth's magnetic field lines. Next we will develop the software modules for post-flight calibrations using the Earth's magnetic field model. We expect to finish the software development before the launch of the ST-5 spacecraft. The final data products are the fully calibrated magnetic field data in geophysical coordinate systems. These data can be readily used to study the variability of the field-aligned currents in the auroral zone.

Component Level

Individual components such as the transponder, cold gas micro-thruster and antennas were tested at the component level to vibration and thermal vacuum requirements as specified in ST5-495-007, Component Test Requirements and Guidelines. We were able to verify the performance requirements for many of the technologies at the component level.

The performance (data rate, bit error rate) of the transponder was measured during thermal vacuum testing, as well as during compatibility testing of the prototype transponder with the Deep Space Network and McMurdo Ground Station components. For the Cold Gas Micro-Thruster, we verified opening and closing of the thruster over its complete temperature range, and measured Isp and thrust as a function of pressure. The Variable Emittance Coating radiators were calibrated during spacecraft-level thermal balance/thermal vacuum testing. For the power system, performance testing measured voltage, current, and capacity. The magnetometer was characterized at GSFC's magnetics testing facility. Pattern testing of the RF antennas was conducted using a mockup ST5 spacecraft. The transponder and RF antennas' performance was also characterized using a ground support equipment RF "hat."

Spacecraft Level

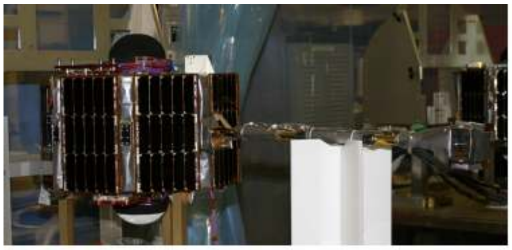
The relevant environments for the spacecraft are: the launch environment (vibration, shock), the space environment (thermal vacuum, radiation exposure), and the need to demonstrate a science capability (magnetic cleanliness). The tolerance of the spacecraft to radiation exposure is demonstrated analytically and through part-level radiation tolerance testing for Single Event Upset (SEU) and Total Ionizing Dose (TID). A radiation model was developed based on the planned mission orbit and spacecraft design. Spacecraft-level vibration, shock and thermal vacuum testing is performed during spacecraft I&T. The spacecraft's mass and magnetic signature are also measured during spacecraft I&T.

Most of the performance criteria that were tested at the component level were re-verified during spacecraft-level testing. Comprehensive Performance Tests were developed and run during thermal vacuum testing to verify that the components and spacecraft as a whole were performing as specified.

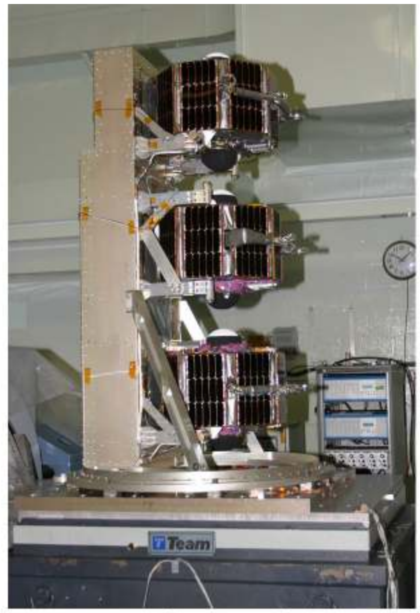
Currently, all components have been delivered, and integrated onto the three spacecraft. The three spacecraft and the Pegasus Support Structure have completed all environmental testing and are currently being prepared for launch at Vandenberg Air Force Base. Some photos from the spacecraft-level testing are shown in **Figure 3**.

Pegasus Support Structure

It was critical to demonstrate that the Pegasus Support Structure (PSS) deployment mechanisms would deploy the spacecraft on-orbit. The PSS was vibration tested with the flight spacecraft, with test deployments of the flight spacecraft performed before and after the vibration test. For these tests, a counterweight was used for G-negation of the flight spacecraft. During thermal vacuum testing of the PSS, test deployments onto a test fixture were performed using an Engineering Test Unit spacecraft and two mass mockups. These test deployments took place at cold temperatures, and with thermal gradients applied across the structure.

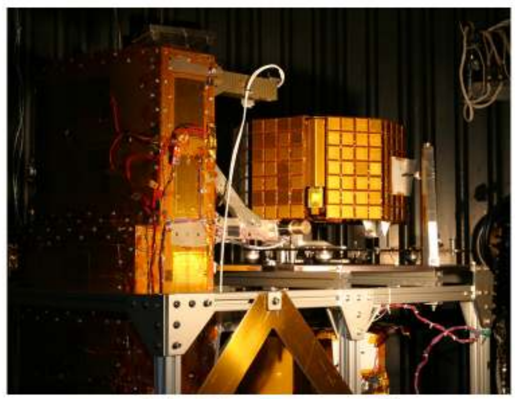


ST5 Spacecraft



Pegasus Support Structure
and Spacecraft Vibration Testing

Test deployment of flight spacecraft
from Pegasus Support Structure



Test deployment from
Pegasus Support Structure
in Thermal Vac

Spacecraft 2 and 3 in Thermal Vacuum Chamber

Figure 3, ST5 TESTING

3. On-Orbit Validation Plans

Although all components, the spacecraft as a whole, and the ground system have thoroughly been tested during I&T, the "proof of the pudding" is verifying the performance on-orbit. This will advance the technologies to New Millennium Program's Technology Readiness Level 7, "prototype demonstration in a space environment."

Constellation Operations Validation Flight Test

The ST5 spacecraft will be configured into constellation geometries, as described in **Figure 4**. The spacecraft will be operated as a constellation and lessons learned will be documented. Definitive clock correlation is performed post-pass using three methods: Return Data Delay, oscillator calibration (thermal modeling) and sun pulse. Operations personnel will conduct a one-week "hands off" test of the autonomy features of the ground system and spacecraft.

Science Measurement Validation Plan

The ST5 constellation validation plan will utilize magnetic field measurements from 3 micro-satellites formation flying in the manner displayed schematically in **Figure 4**. The planned 300 x 4500 km high inclination, sun-synchronous orbit will result in the ST5 spacecraft passing over the Earth's auroral zones 4 times per orbit for a total of 40 times for a total of ~ 3600 field-aligned current crossings over the 90 day mission.

Formation Flying–The ST5 measurement concept requires that the 3 micro-satellites execute and maintain pre-determined formations. For each formation the separations must be achieved in specified periods of time before moving to a new formation. Separations of tens of kilometers to several hundred kilometers are required in order to obtain the constellation measurements described. Spacecraft attitude will be maintained such that the spin axis of the spacecraft is pointed to within 10-15 degrees of ecliptic north. Specifically, the ST5 mission plan consists of two measurement-concept driven formations.

Formation #1 (Sci Val 1)–Spacecraft separations will evolve to achieve separations of spacecraft 1 to 2 of 40-100 km and spacecraft 2 to 3 of 80-200 km by Day 30. Initial constellation performance assessments and measurement concept validations are to be performed and field-aligned current motion, thickness, current density and temporal stability determinations made during this interval.

Formation #2 (Sci Val 2)–Spacecraft separations will evolve to achieve separations of spacecraft 1 to 2 of 20-60 km and spacecraft 2 to 3 of 60-150 km by Day 60. Further constellation performance assessments will be conducted and measurement concept validations will be performed and field-aligned current motion, thickness, current density and temporal stability determinations made during over these new spatial scale lengths.

Finally, correlation analysis of the 3 spacecraft pairs of magnetic field measurements will also be used to assess the importance of temporal variability of the field-aligned currents. In theory, the field-aligned current systems linking the auroral oval to the magnetosphere are considered to be "standing" Alfven waves. The validity of this model depends upon the time scales for the temporal availability of these currents. Given the very high speed of Alfven waves in the high latitude magnetosphere, up to at least 5000 km/s, the "bounce time" for these waves between the auroral ionosphere and the dynamic regions of the night-side magnetosphere are estimated to be several seconds to a few 10s of seconds. For this reason it is especially valuable to determine the stability of the field-aligned current systems over time scales of 3 to 30 seconds. Given the orbital speeds of spacecraft in low Earth orbit, ~ 8 km/s, the implied spacecraft separations to measure time variations on these time scales is ~ 25 km to 250 km.

ST5 Spacecraft Validation–Specific flight validation tests will be run over the course of the 3-month mission life. Each validation test will have a specific technology or science validation objective. The validation tests are designed to work within the constraints of available power and ground contacts. Normal operations are done in parallel with validation activities. As much as possible, the flight performance of the technologies will be compared to the results achieved during ground testing, which is in turn compared to analytically predicted performance. This ensures that proper validation of the technology is achieved for the specific implementation of the technology as well as the general principles driving the technology. The technologies can then be scaled, modified or directly infused into future missions. In some cases, in the flight environment, a technology can operate over only a subset of the complete application envelope. Thus, more thorough testing on the ground is conducted than can be directly achieved in space. The spacecraft magnetic characteristics will also be measured in flight.

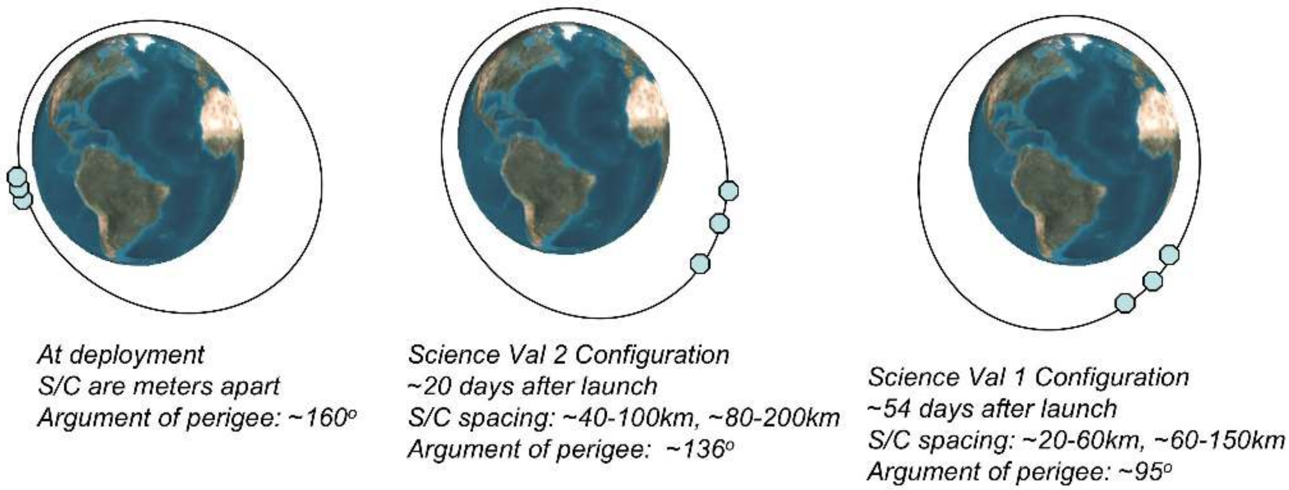


Figure 4, ST5 Constellation Formations

Miniature Communications Transponder–The transponder will be used throughout the mission for command, telemetry, and radiometric orbit determination (two-way Doppler). During the Launch and Early Orbit period, validation tests will be dedicated to assessing the performance of the transponder. As part of this validation testing, we will cycle through different configurations of the transponder and check out its functionality and performance for off-nominal operations. Telemetry that will be used to assess the transponder performance includes Automatic Gain Control, Receiver Carrier Loop Stress, transmitter output power and oscillator temperature. On the ground, we will assess the received signal strength and bit error rate.

Cold Gas Micro-Thrusters–The Cold Gas Micro-Thruster will be used on-orbit during initial sun acquisition, for constellation maneuvers and for spacecraft attitude control. The flight performance of the thruster will be assessed using telemetry from the pressure transducer, thruster thermistor, propellant tank thermistor and accumulated thruster on-time. Pre- and post-maneuver attitude and orbit determinations will also be used to assess the on-orbit performance of the thruster. These telemetry data will be used to develop a more accurate analytical model of the thruster for predicting performance in a space environment. In addition to performance validation, flight data will be used to assess other parameters such as pulse to pulse variability and long term thrust degradation due to usage. At the end of mission life, the thruster will be operated in a steady state mode to verify its steady state mode capability.

Variable Emittance Coatings (VECs)–In order to determine the effect of the space environment on the Variable Emittance Coatings radiator, each technology will be operated at regular intervals during the mission. The technologies will operate no less than a total of 100 hours each. At a minimum, each Variable Emittance Coatings will be operated at one-week intervals, thus providing time-phased assessment of performance. Each technology will be allocated a 1.5W heater. Since the Variable Emittance Coatings radiator is isolated from the spacecraft, the heater is necessary to assess its performance. The technology can operate with or without the heater. The correlated thermal model will be used along with the flight data to determine on-orbit performance.

CMOS Ultra-Low Power Radiation Tolerant (CULPRiT) Logic–The CULPRiT chip will be operated for most of the ST5 mission. Specific validation tests will be accomplished by varying operational parameters. Voltage and current telemetry, as well as ground-based analysis of Reed Solomon decoding errors will be used to demonstrate its performance. An on-board continuous monitor of encoding errors will be conducted. This is achieved by comparing the code word produced by the CULPRiT Reed Solomon encoder to that of a standard logic radiation-tolerant Reed Solomon encoder. Any mis-comparisons between the two encoders will be counted and sent via telemetry to the ground. The space radiation environment, to which CULPRiT is subjected, will be estimated using analysis of solar array voltage and current degradation as well as the accumulation and frequency of single and multi-bit errors within the Dynamic Random Access Memory of the C&DH.

Low Voltage Power Subsystem Components–The solar arrays and lithium-ion battery are used routinely to power the spacecraft throughout the mission. Voltage and current telemetry from the power system will be used to assess the performance of these elements.

Miniature Magnetometer–The ST5 magnetometer shall be powered on for at least 3 complete orbits per week to achieve science validation goals. Science validation will include in-flight calibration (including three spacecraft inter-calibration), de-spinning the data, and performing ST5 science validation.

The following tasks will be performed in the science validation process with ST5 magnetometer data:

The magnetometer boom deployment will be monitored using the MAG data. The data will be analyzed to determine the alignment between the magnetometer boom and the spacecraft spin axis.

The data will be analyzed to detect and characterize spacecraft transients such as nutation following thruster firing and boom oscillations or twisting.

Spin-plane magnetometer offsets will be monitored throughout the mission life to evaluate the stability of any magnetic field generated by the spacecraft. For example, solar array anomalies or shorts can change the spacecraft magnetic field and may be detected from analysis of the magnetic field measurements.

Power spectral analysis will be performed on the magnetic field measurements in order to assess MAG noise level and to any detect spectral peaks caused by spacecraft interference.

Science events in the MAG data will be analyzed to demonstrate the capability of the miniaturized magnetometer and to validate the suitability of ST5 as a science platform.

Inter-spacecraft calibration will be performed to evaluate the repeatability in manufacturing a magnetically clean miniature spacecraft.

Power spectra computed on the ground will be analyzed to determine the intrinsic noise level of the magnetometer and to identify any time variable magnetic fields or interference associated with the spacecraft. Analysis and modeling of the modulation of the measured magnetic field at the spin frequency of the spacecraft (i.e., the "spin tone") will allow the measurement and tracking of the components of any spacecraft magnetic field perpendicular to the spin axis direction. The magnitude of the component of any spacecraft magnetic field along the spin axis direction will be determined by comparing full orbit data against the International Geomagnetic Reference Field[3]. Finally, the magnetic field measurements will be used to detect and characterize the deployed boom orientation and stability as well as any spacecraft nutation or coning.

[3] The International Geomagnetic Reference Field is determined based on all available data sources of geomagnetic measurements including ground-based observatories, ships, aircrafts and satellites.

Miniature spinning sun sensor–The sun sensor is used during normal operations to determine the sun angle. Its performance (field of view, resolution, accuracy) can be assessed by comparison with data from the magnetometer.

X-band Antenna–The X-band antenna is used routinely for communications throughout the mission, and will be assessed along with the transponder. Assessment of antenna gain performance and power handling efficiency will be made from on board telemetry of RF Power output, received Automatic Gain Control and Carrier Loop Stress combined with ground receipt Automatic Gain Control and knowledge of the spacecraft's orbit and attitude.

Spacecraft Deployment Mechanism–The performance of the deployment mechanism on the Pegasus Support Structure, as well as the Pegasus Support Structure itself are demonstrated by the successful deployment of the flight spacecraft at the desired spin rate. This can be assessed using telemetry from the sun sensor (pulses correlate to spin rate), magnetometer (attitude determination) and ground tracking (spacecraft position).

Magnetometer Deployment Boom–The magnetometer boom deploys the magnetometer early in the mission, then maintains the instrument in position to within ¼ degree and 1 cm radius. Its performance will be assessed using magnetometer measurement data.

Nutation Damper–The nutation damper will damp out any nutation introduced during initial deployment from the launch vehicle or thruster firing. Its performance will be assessed based on spacecraft attitude data from either the sun sensor or the magnetometer.

4. CONCLUSION

We have made good progress in our validation strategy for science capability, constellation operations, and spacecraft and component technologies. Our ground testing has allowed us to partially validate the technologies, and we will complete the technology validation during our 90-day mission. We are on target for our February 28, 2006 launch date.

REFERENCES

[1] Candace C. Carlisle, Evan H. Webb, and James A. Slavin, "Space Technology 5–Changing the Mission Design without Changing the Hardware," 2005 IEEE Aerospace Conference Proceedings, March 2005.

BIOGRAPHY

Candace Carlisle is the ST5 Deputy Project Manager at NASA's Goddard Space Flight Center. Prior to ST5, she worked in System Engineering roles on the Earth Observing Data and Information System and the Network Control Center for the Tracking and Data Relay Satellite System. She has a BS in Computer Science and Physics from the College of William and Mary, and MS degrees in Computer Science and Technical Management from the Johns Hopkins University.

Guan Le is the Science Validation Lead for ST-5. She is an astrophysicist in the Geospace Physics Branch of the Laboratory for Solar and Space Physics at NASA Goddard Space Flight Center. She received her Ph.D. in space physics from the University of California, Los Angeles. Prior to GSFC, she was a research geophysicist at Institute of Geophysics and Planetary Physics, University of California, Los Angeles.

James A. Slavin is the ST-5 Project Scientist and the Chief of Laboratory for Solar and Space Physics at the NASA GSFC. He received his doctorate in Space Physics from the University of California at Los Angeles. His previous positions include staff scientist at the Caltech/Jet Propulsion Laboratory, Discipline Scientist for Magnetospheric Physics at NASA Headquarters, and Head of the Geospace Physics Branch at NASA GSFC.

J. Timothy Van Sant is a Technology Manager for the Sun-Earth Connection Program Office at NASA Goddard Space Flight Center. He has served as the Sun-Solar System Connection Theme Technologist since 1999 coordinating and advocating technology development important to future strategic missions. He is also currently leading a Concept Definition Study for a Solar Sail mission that will be proposed for the New Millennium Program's ST-9 opportunity. He has worked for 20 years at NASA Goddard Space Flight Center, the bulk of the time as a Materials Engineer supporting flight projects such as the Hubble Space Telescope (HST) and the Wilkinson Microwave Anisotropy Probe (WMAP).

Evan Webb is the ST5 Mission Systems Engineer. Before working on ST5 he was a participant in the GSFC-AETD Systems Engineering Education Development (SEED) program, and worked as a systems engineer on the Landsat Data Continuity Mission. He was the lead engineer for the SpaceLAN rad-hard Ethernet development effort at GSFC, and prior to that he was the hardware lead engineer for the WARP solid state recorder on EO-1. His interests outside of work include wine collecting, classical piano, and sports car racing. He has Master's and Advanced Master's of Science in Electrical Engineering from Johns Hopkins University, and a BS in Electrical Engineering from the University of Maryland.