5.0 INTEGRATION AND TEST (I&T)

In order to meet the current Solar TErrestrial RElations Observatory (STEREO) schedule it will be necessary to integrate and test two spacecraft in 10 months. This is an aggressive schedule, almost demanding that the two spacecraft be integrated concurrently. Concurrent integration, however, is not feasible due to the significant cost implications. This implies that the Integration and Test period must be well planned with contingencies taken into account for both spacecraft. The section provides an overview of the I&T portion of the program, detailed planning will occur during the rest of Pre-Phase A and during Phase A/B.

5.1 Overview

The two STEREO spacecraft will be integrated at The Johns Hopkins University Applied Physics Laboratory (JHU/APL) with environmental testing occurring at both APL and the Goddard Space Flight Center (GSFC) in a FED-STD-209E class clean area. The STEREO testing philosophy will be based on APL document SDO 2387-1, MIL-STD-1540B, and GEVS-SE.

In order to meet the tight I&T schedule, the two spacecraft will be integrated and functionally tested as if they were a single redundant spacecraft with a side A and a side B. This means that a subsystem is integrated onto the first spacecraft, functionally tested and then the same subsystem is integrated onto the second spacecraft. This occurs on intervals of about two weeks. The same integration method would apply to instruments as well.

The methodology has several benefits:

- Allows the I&T team to remain in the same testing configuration for both spacecraft.
- Allows the I&T team to apply lessons learned from one spacecraft to the second.
- Permits the use of a single I&T team.

Once the spacecraft are integrated, they will be tested for performance and function concurrently, using a single I&T team and Ground Support System (GSS). Dual Ground Support Equipment (GSE) for power, RF and instruments will be required. Once functional and performance testing is complete, the spacecraft will be environmentally tested in a linear fashion except for thermal-vacuum testing which will occur concurrently. After thermal-vacuum testing at GSFC, the spacecraft are shipped for launch. A Pre-Ship Review is scheduled prior to packing of the spacecraft.

GSE Requirements. It is planned that, each spacecraft will have its own subsystem GSE that will follow the spacecraft throughout the I&T process. This equipment consists of a Block-House Charging Unit (BCU) for the powering spacecraft during ground tests, RF interface equipment racks for actuating the RF equipment, Solar Array Simulators (SAS) for powering the spacecraft, and the GSE for operating all the spacecraft instruments.

Both spacecraft will be operated from one GSS, which will transition into Mission Operations once I&T at APL is finished. The GSS is used to run scripts that functionally test the spacecraft and display spacecraft telemetry data. It can also operate via a network connection.

I&T Personnel. The Integration and Test team will be made up of dedicated I&T personnel, subsystem support, personnel from the Mission Operations Team (MOT) and system engineering. I&T personnel will be used to plan the I&T process, physically integrate and test the subsystem flight hardware as it is integrated on to the spacecraft, validate system level functional and performance requirements and environmentally test the spacecraft. The I&T team is also responsible for all remote activities including testing at GSFC and launch site operations.

The I&T team is supported by the subsystem leads during subsystem integration and system functional/performance testing. The MOT is used during I&T for two reasons. First, the MOT bolsters the I&T team during a relatively intensive portion of the spacecraft development schedule. Secondly, it provides the MOT with experience operating the spacecraft. One of the goals is to operate the spacecraft during I&T as if it were on-orbit. The System Engineer's role during I&T is to make sure that all requirements are validated and that autonomy is fully tested and operates as designed.

Cleanliness. The STEREO spacecraft have two cleanliness requirements. Class 100,000 prior to integration of several of the instruments and class 10,000 during and after these instruments are integrated. This will necessitate that the class 100,000 environment be transitioned to a class 10,000 one for the instruments. The goal is to make this transition as late as possible. With all other things being equal, the class 10,000 instruments will be held until last to be integrated on to the spacecraft

Prior to integration of the class 10,000 instruments, the spacecraft and clean room will be scrubbed to a class 10,000 level. This will be verified by the use of witness plates and air sampling. This verification will be performed by APL's Reliability and Quality Group. Another option of maintaining a Class 10,000 just around the instruments (bagging) will also be evaluated when instrument teams are engaged.

A detailed Contamination Control plan will be written during the next phase of APL's effort. It will address contamination in general as well as providing details from a class 100,000 to a class 10,000 environment.

5.2 Spacecraft Integration and Test Flow

The objectives of I&T portion of the program is to test the two STEREO spacecraft under ambient conditions and simulated environments in order to establish correct operations of all subsystems and instruments, when interconnected as a spacecraft. This confirms that all electrical interfaces between spacecraft and instruments are in compliance with specifications and/or interface control documents. The performance of the spacecraft will be validated and recorded as a baseline by system performance testing at several points in the testing process. Furthermore, the spacecraft is required to display quality of workmanship by demonstrating performance under mission-level environmental stress.

Integration of the STEREO spacecraft starts after the structure, propulsion and harness have been delivered as a unit. Subsystem integration will be completed in the order outlined in Figure 5-1. The integration effort will ping-pong between the two spacecraft. This allows both spacecraft to maintain schedule and lessons learned on the first spacecraft to be applied to the second. The subsystem integration order was chosen to facilitate testing. Instruments are integrated next to last, with the instruments requiring a Class 10,000 environment integrated last.

Spacecraft Integration. The two STEREO spacecraft will undergo integration and performance/functional testing in the APL Clean Room in the Kershner Space Integration and Test Facility (Building 23). Environmental testing will occur at APL and the environmental test areas of GSFC Environmental Test Engineering Branch Facility (Buildings 7 and 10).

Tests that occur in the APL clean room will include functional testing of all components, subsystems, and instruments. Performance testing will then be conducted to establish a "baseline of data" from the spacecraft to compare with testing during the environmental test program and flight operations.

Spacecraft subsystems and instruments for both STEREO spacecraft are to be delivered flight qualified and fully integrated so as to meet the

schedule outlined in Figure 5-1. Figure 5-1 is labeled in months prior to launch site delivery. The I&T schedule officially runs from the point when the first subsystem is ready to be integrated on to the spacecraft structure to launch site shipping. I&T preparation and planning starts much earlier and runs from Pre-Phase A through A/B and onto C/D.

Subsystem integration occurs in the following order, on to an already integrated structure, harness, and propulsion system:

1. Power electronics and battery (Solar Array Simulator is used for test, solar arrays are installed just before vibration, "work" batter is install for initial integration, flight battery is installed before performance test period)
2. RF Subsystem (Antennas, TWTA, switches, diplexers and coax)
3. IEM (C&DH, Uplink and Downlink cards)
4. G&C Subsystem (attitude interface electronics, Guidance and Control Computer, RWAs and electronics, IMU, star tracker, propulsion system, DSADs and electronics.
5. Instrument 1
6. Instrument 2
7. Instrument 3
8. Instrument 4
9. Instrument 5 (Class 10,000 assumed)
10. Instrument 6 (Class 10,000 assumed)
11. STEREO 1 & 2 Ordnance and Thermal Systems (all pyro-ordnance devices, ie.: Booms, deployers, covers or lids for instruments. Thermal heaters, temperature sensors, and multi-layer insulation (MLI).

Each subsystem is allocated approximately two weeks per spacecraft for physically integrating the subsystem and functional test. Time consuming tasks such as alignments are saved until later in the schedule . Instrument integration can theoretically occur in the order that they are delivered, however, it is preferable that the class 10,000 instruments be integrated last.

The order for subsystem integration was chosen such that the spacecraft can be tested in ever increasing levels of complexity. For example, none of the spacecraft could be tested without a power subsystem, therefore power is integrated first.

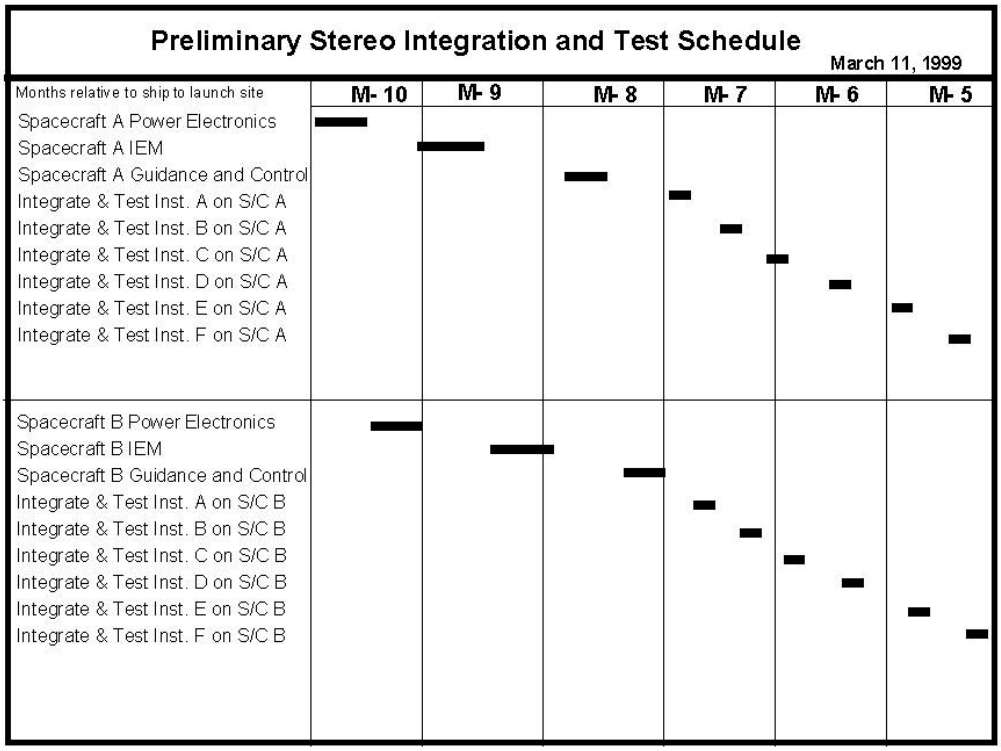
The last items to be integrated and functionally tested are ordnance and thermal systems. Ordnance systems are integrated next to last due to the changes in handling procedures when live ordnance is on the spacecraft. Thermal systems are held until last because they limit access to the spacecraft.

Spacecraft Environmental Testing

Once integrated, the spacecraft will go through a series of environmental tests with a goal of ascertaining proof of performance under the environmental loads that the spacecraft will see during launch, fly-out and operations. Mass properties for each spacecraft are also confirmed during this period.

Environmental testing for each spacecraft will also occur in a ping-pong fashion, except for thermal-vacuum testing. Due to the long period of time needed for thermal-vacuum testing, both spacecraft will be tested at the same time. Thermal-vacuum testing will occur at GSFC. A detailed thermal-vacuum study will be performed during the remainder of Pre-Phase A.

Prior to thermal-vacuum testing the spacecraft will undergo, random vibration, sine/load testing, shock testing and acoustic testing (at GSFC). After each of the major environmental tests, spacecraft performance will be verified against the baseline set during integration. Mechanical alignments will also be checked. Prior to thermal-vacuum testing, mass properties and spin balancing occurs for each of the vehicles. Spin balancing is only required for the Athena II launch.



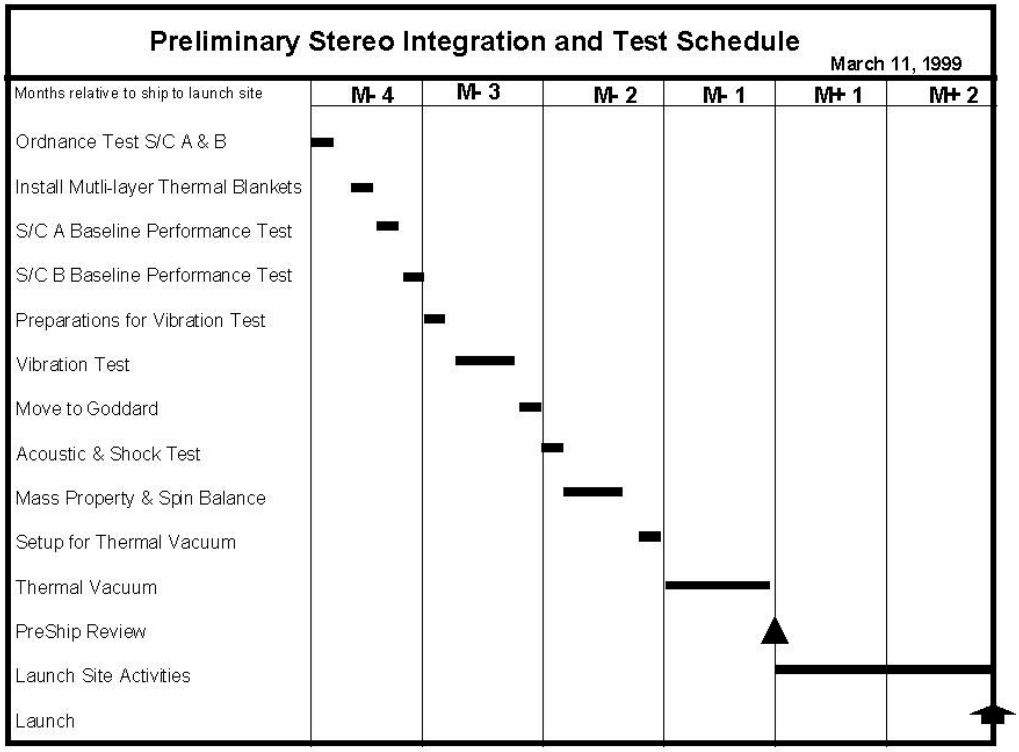


Figure 5-1 STEREO Integration and Test Flow