Deep Space Payload Launches via the Space Transportation System

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Beginning with the Galileo spacecraft launch in 1985, deep space payloads will be launched via the Space Shuttle. This change from the previous use of expendable launch vehicles will introduce large changes in procedures and data flow configurations for both the flight project and the Deep Space Network during the launch period. This article describes a typical Galileo launch period sequence of events and telemetry and command data flow configurations.

I. Introduction

Starting with the launch of the Galileo spacecraft, now scheduled for 1985, deep space payloads will be launched via the Space Shuttle vehicle of the Space Transportation System (STS), in sharp contrast to all previous launches of deep space payloads via expendable launch vehicles. This very significant change in method of launch will result in large procedural changes for both flight projects and the Deep Space Network (DSN), in its capacity as lead support network for all deep space missions. In a previous article (Ref. 1), the Space Shuttle impact on the DSN initial acquisition was described; in this article, procedural differences for the flight project and DSN during the pre and postlaunch periods are examined. In particular, major subphases of the pre and postlaunch period are identified, and telemetry and command data flow configurations are presented for each subphase. The Galileo mission is used to exemplify a typical launch period sequence of events and data flow configurations.

Major differences for the flight project and DSN in the upcoming Space Shuttle era are the larger number of subphases in the launch period (e.g., Shuttle on-orbit phase of several hours, for which there was no similar phase in the expendables era) and direct launch involvement of additional NASA centers (e.g., Johnson Space Center) and non-NASA facilities (e.g., Air Force Satellite Control Facility).

Section II describes the nominal Galileo sequence of events during the launch period, Section III identifies major launch period subphases, while Section IV identifies the telemetry and command data flow configurations for each of the launch period subphases.

II. The Nominal Galileo Sequence of Events

As previously mentioned, the Galileo spacecraft is currently scheduled for a 1985 launch. The overall launch period begins with the transporting of the spacecraft to the Kennedy Space Center (KSC), extends through liftoff, and terminates with a successful DSN initial acquisition. Typical prelaunch (prior to liftoff) and postlaunch (following liftoff) Galileo sequences of events are described in detail below.

A. Nominal Galileo Prelaunch Sequence of Events

The Galileo spacecraft is transported from the Jet Propulsion Laboratory (JPL) to the Kennedy Space Center (KSC) by a United States Air Force C-5A aircraft. After being unpacked in the Spacecraft Assembly and Encapsulation Facility (SAEF), the spacecraft is inspected to determine if any damage was sustained during transit. Baseline tests, including the use of S- and X-band radio frequency (RF) subsystems, are evaluated. At the conclusion of these tests, Radioisotope Thermoelectric Generators (RTGs) are installed on the spacecraft and tests are rerun using the RTGs as the source of electrical power. When these tests are completed, all power is removed from the spacecraft to ensure that the installation of pyrotechnic devices and the loading of consumables in the propulsion system will be carried out in a safe environment. At the conclusion of the propulsion loading and pyrotechnics installation, the spacecraft will again be activated for further testing and will be prepared for transfer to the Vertical Processing Facility (VPF). At the VPF the spacecraft will be mated to the Spacecraft Injection Module and the two Inertial Upper Stage (IUS) stages. End-to-end tests via the Merritt Island Launch Area DSN Facility (MIL 71), IUS, and Space Shuttle communications routes will be performed. A series of operational tests will also be conducted. Upon satisfactory completion of these tests, the spacecraft will be placed into the storage mode to await shipment to the launch pad. About ten days before launch, the spacecraft will be removed from storage and transported to the launch pad, preceding the Shuttle arrival by two days. After cargo preparation procedures are completed the spacecraft will be installed in the Shuttle Orbiter Bay. The RTGs are then reinstalled in the spacecraft. Final end-to-end communications tests using MIL 71 (hardline only) and Space Transportation System (STS) Tracking Data Relay Satellite (TDRS) communications links will be conducted. These tests should last about four days. At their conclusion the launch countdown will commence.

Figure 1 presents the nominal Galileo prelaunch sequence of events for an early May 1985 launch.

B. Nominal Galileo Postlaunch Sequence of Events

About one hour after liftoff, the project will commence checking out the condition of the spacecraft to see if the vibration and acceleration forces encountered during the powered portion of the Shuttle flight have affected the observed prelaunch condition of the spacecraft. The telemetry checkout will be via the STS-TDRS communications link. If required, updated commands may be sent to the spacecraft via this same communications link. A decision to continue with the planned flight to Jupiter must be made by L plus 7.5 hours.

If a "go" decision is made, a Spacecraft-Shuttle separation should occur during the sixth Shuttle orbit, about 8.5 hours after launch. During the more favorable periods of the launch window, the separation could be delayed until the seventh or eighth orbit without jeopardizing the objectives of the mission. After separation, an IUS S-band link can be used to route data between the spacecraft and the shuttle. The maximum useful range of this link is 20 kilometers. At longer ranges it will require the IUS communications network to provide IUS performance and Galileo telemetry data.

About 45 minutes after separation, the IUS first-stage engine will burn until the propellant is exhausted; during the engine burn the Galileo transmitter will be turned on. Separation of the first stage will occur about 10 seconds after fuel depletion. Thirty-five seconds later the IUS second stage will commence a one minute and 40-second burn. Fifty seconds after burnout, the second stage will separate. The spacecraft transponder will now be the only means of exchanging data between the flight project and the spacecraft. Fifteen seconds later the injection module engine will start, and shortly after engine start the spacecraft boom will be deployed. After an 85-second burn, the engine will stop for approximately 10 seconds, and then restart for a 50-second burn. During this second burn, the spacecraft will be rotated to achieve spin stability. After fuel depletion, the injection module will separate from the spacecraft. The injection module will then perform a maneuver to avoid the same trajectory path as the Galileo spacecraft.

Figure 2 presents the nominal Galileo postlaunch sequence of events.

III. Major Launch Subphases During a Shuttle Deep Space Payload Launch

The overall launch period of a deep space payload launch is conveniently subdivided into three major categories, as follows:

(1) Prelaunch phase.

(2) Shuttle attached phase.

(3) Shuttle detached phase.

These are described as follows.

A. Prelaunch Phase

This phase starts with spacecraft assembly in the Spacecraft Assembly and Encapsulation Facility, and includes that time the spacecraft spends in test at the Vertical Processing Facility, and finally the move to the launch pad. This phase terminates with liftoff from the pad. Subphases during the prelaunch period are identified as:

(1) Spacecraft Assembly and Encapsulation Facility.

(2) Vertical Processing Facility.

(3) Launch pad.

B. Shuttle Attached Phase

This phase starts at the moment of liftoff, and proceeds through the Shuttle ascent and the Shuttle on-orbit operations. This phase is terminated when the IUS-spacecraft is placed outside the Shuttle Orbiter. Subphases during the shuttle attached phase are identified as:

(1) Shuttle ascent.

(2) Shuttle on-orbit.

C. Shuttle Detached Phase

This phase starts when the IUS-spacecraft is placed outside the Shuttle vehicle, and proceeds through the IUS burn and spacecraft injection module burn. This phase terminates with a successful DSN initial acquisition. Subphases during the Shuttle detached phase are identified as:

(1) IUS burn.

(2) Spacecraft injection module burn.

IV. Galileo Telemetry and Command Data Flow Configurations During the Launch Period

There are 4 major telemetry and 2 major command data flow configurations during the launch period, and these are detailed as follows:

A. Galileo Spacecraft—DSN

This path exists for both telemetry and command data. The link between the spacecraft and the Merritt Island Launch Area (MILA) DSN facility (MIL 71) is both radio frequency (RF) and hardline. Communications from MIL 71 to the JPL Mission Control and Computing Center (MCCC) is via the JPL Ground Communications Facility (GCF).

B. Galileo Spacecraft—TDRSS

This path is for telemetry data only. The link between the spacecraft and the MILA Ground Spacecraft Tracking and Data Network (GSTDN) station is RF. From the GSTDN station an RF uplink is established to the Tracking and Data Relay Satellite (TDRS). Alternately, an RF link can be established directly from the spacecraft to TDRS. From TDRS, an RF downlink is established to the White Sands Ground Station (WSGS). From there, the data is transmitted via domestic satellite (DOMSAT) to the Goddard Space Flight Center (GSFC) NASA Communications (NASCOM) switching center, and thence through DOMSAT to JPL MCCC.

C. Galileo Spacecraft—IUS

This path is for telemetry data only. Galileo telemetry is embedded in IUS telemetry. An RF link is established from the IUS to the Air Force Space Ground Link System (SGLS). The Galileo/IUS data is transmitted to the Air Force Satellite Control Facility (AFSCF), where Galileo telemetry is stripped out and transmitted via GSFC NASCOM switching to JPL MCCC.

D. Galileo Spacecraft—Shuttle

This path is for both telemetry and command. For telemetry, the link can be direct from the Galileo spacecraft to the Shuttle Orbiter, or embedded in IUS telemetry data to the Shuttle Orbiter. From Shuttle the link is RF to TDRS to WSGS. From WSGS, the data is transmitted via GSFC NASCOM to Johnson Space Center (JSC) Mission Control Center (MCC). From JSC MCC, Galileo telemetry is stripped out and transmitted via GSFC NASCOM to JPL MCCC. Alternately, IUS/Galileo telemetry is transmitted via GSFC NASCOM to AFSCF, where Galileo telemetry is stripped out and provided through GSFC NASCOM to JPL MCCC.

For command, the link begins with the IUS Control Center, in conjunction with voice communication from JPL MCCC. From the IUS Control Center, the link is to WSGS through GSFC NASCOM, and then RF to TDRS to the Shuttle Orbiter. From the Orbiter, the link is either hardline or RF (IUS-Shuttle Orbiter distance <20 km) to IUS, and finally, to the Galileo spacecraft. For this mode, only a series of eight commands ("discrete commands") is possible.

Figures 3 through 12 illustrate the above data flow paths for the various launch subphases.

Reference

1. Khatib, A. R., Berman, A. L., and Wackley, J. A., "Space Shuttle Launch Era Spacecraft Injection Errors and DSN Initial Acquisition", in *The TDA Progress Report 42-64,* Jet Propulsion Laboratory, Pasadena, California, pp. 80-82, August 15, 1981.

SPACECRAFT EVENT	FACILITY	MIL 71	ACTIVITY
• INSPECTION, BASELINE TEST	S/C ASSEMBLY AND ENCAPSULATION	✓	S-AND X-BAND T/R
• INSTALL/TEST RTG	S/C ASSEMBLY AND ENCAPSULATION	✓	S-AND X-BAND T/R COAX (TLM)
• PROPULSION PREPARATIONS	S/C ASSEMBLY AND ENCAPSULATION	–	NO POWER FOR SPACECRAFT
• BASELINE TEST	S/C ASSEMBLY AND ENCAPSULATION AND VERTICAL PROCESSING	✓	S-BAND RECEIVE COAX (TLM), TDRS, IUS
• INJECTION MODULE/IUS MATE AND TEST	VERTICAL PROCESSING	✓	S-BAND RECEIVE COAX (TLM)
• STORAGE AND BASELINE TEST	VERTICAL PROCESSING	✓	S-BAND RECEIVE COAX (TLM)
• INSTALL IN SHUTTLE CARGO BAY	LAUNCH PAD	–	NO POWER FOR SPACECRAFT
• RTG FINAL INSTALL AND TEST	LAUNCH PAD	✓	S-BAND RECEIVE COAX (TLM)
• END-TO-END TEST	LAUNCH PAD	✓	S-BAND RECEIVE COAX (TLM), IUS, TDRS VIA SHUTTLE
• LAUNCH	LAUNCH PAD	✓	TRACKING AND TELEMETRY VIA IUS AND TDRSS NETWORK

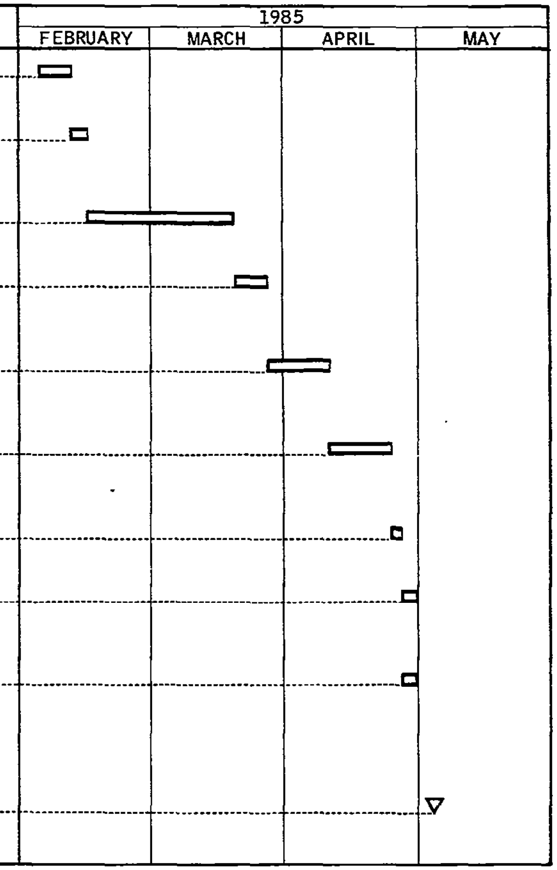
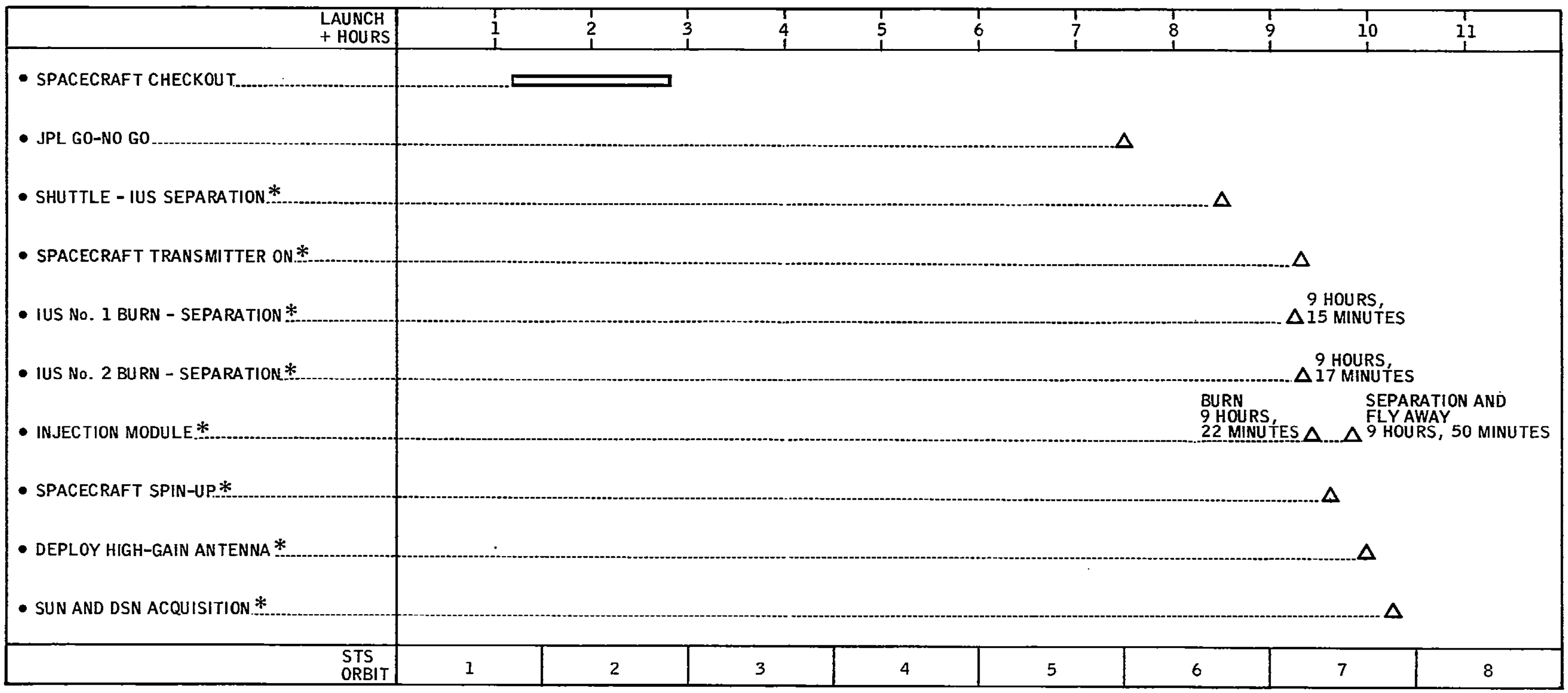


Fig. 1. Nominal Galileo prelaunch sequence of events for an early May 1985 launch



* THIS SEQUENCE COULD BE DELAYED 1 OR 2 ORBITS

Fig. 2. Nominal Galileo postlaunch sequence of events for an early May 1985 launch

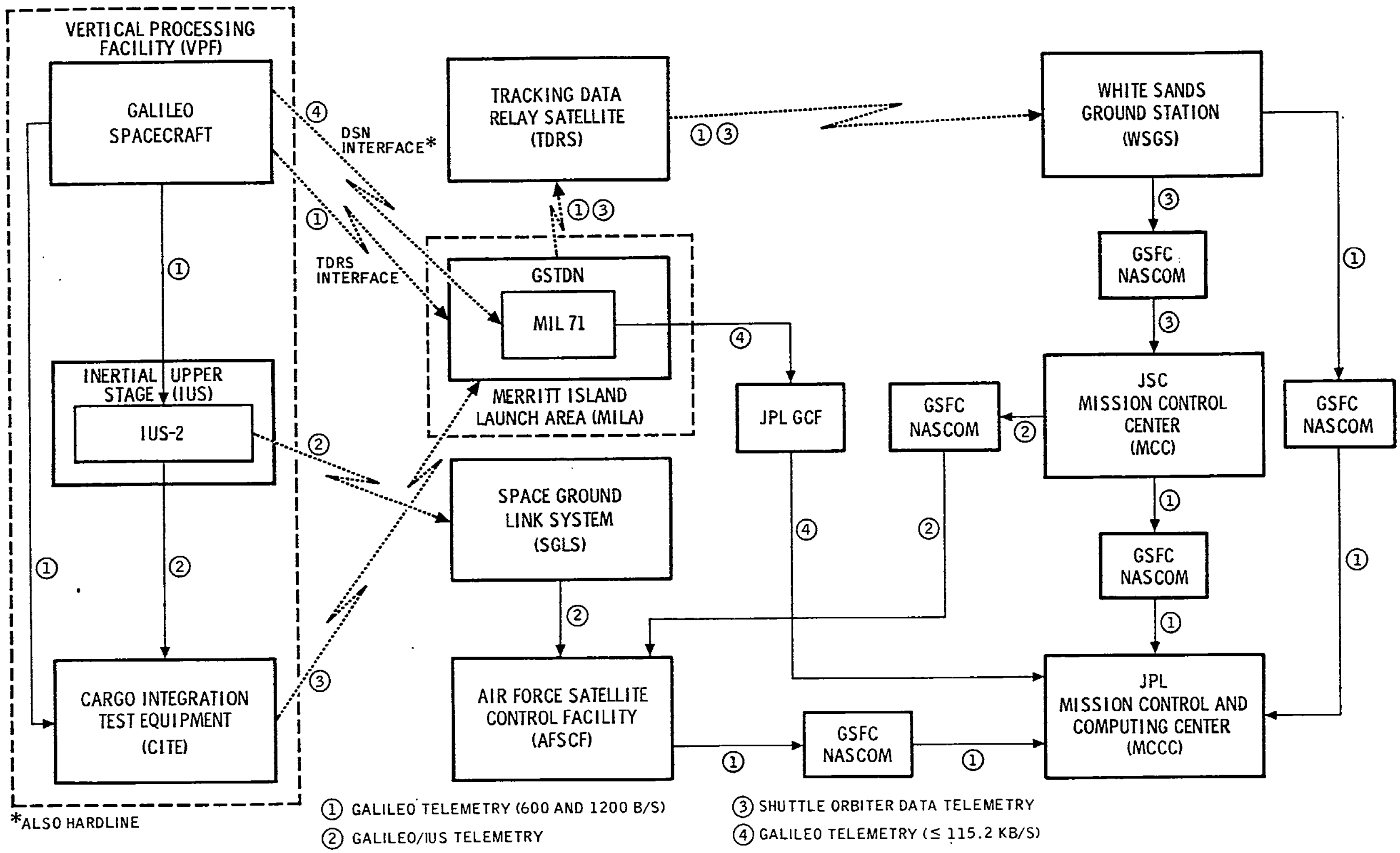
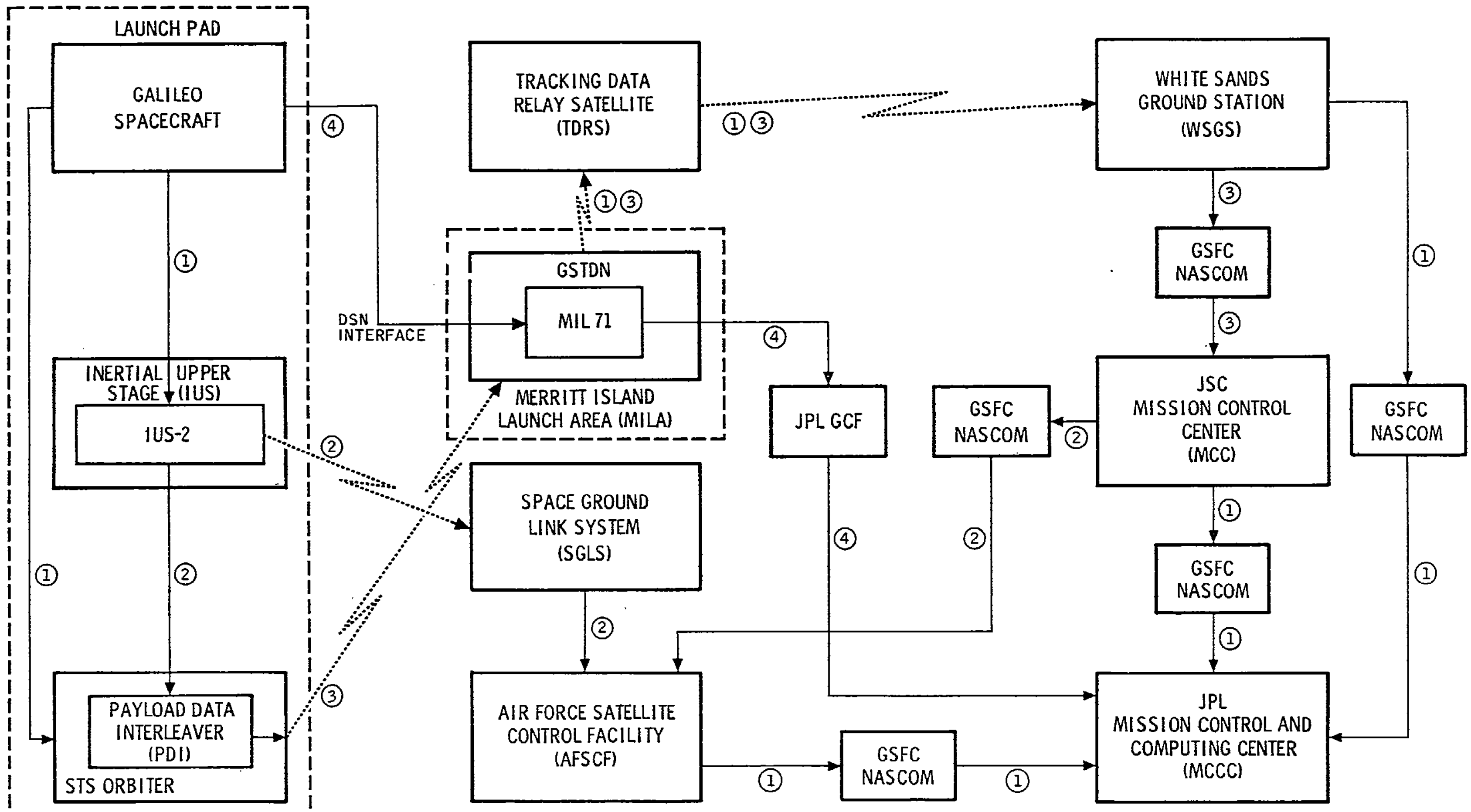


Fig. 3. Telemetry data flow in the prelaunch phase—Vertical Processing Facility subphase



① GALILEO TELEMETRY (600 AND 1200 B/S)
② GALILEO/IUS TELEMETRY
③ SHUTTLE ORBITER DATA TELEMETRY
④ GALILEO TELEMETRY (≤ 115.2 KB/S)

Fig. 4. Telemetry data flow in the prelaunch phase—launch pad subphase

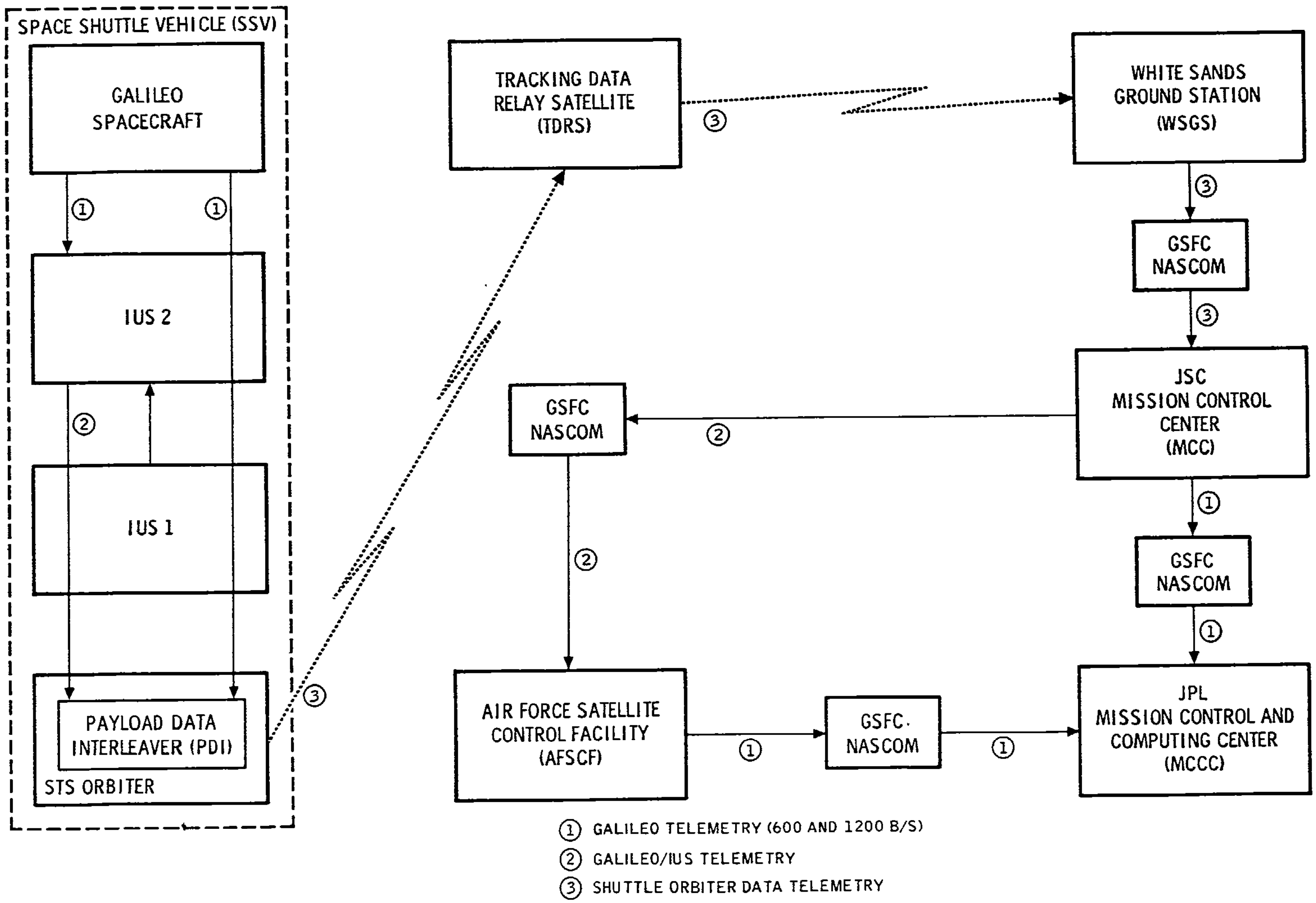


Fig. 5. Telemetry data flow in the Shuttle attached phase—ascent subphase

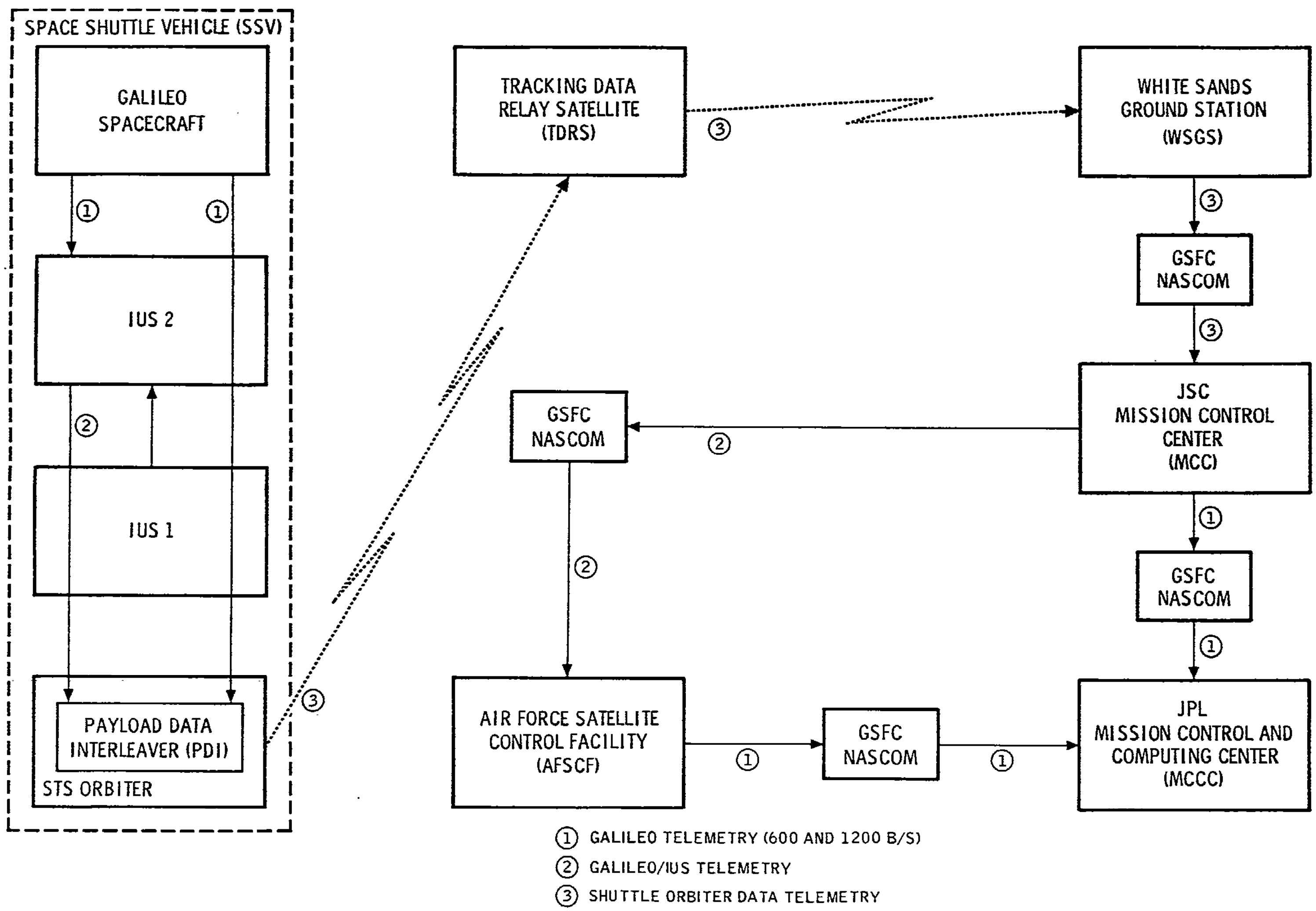
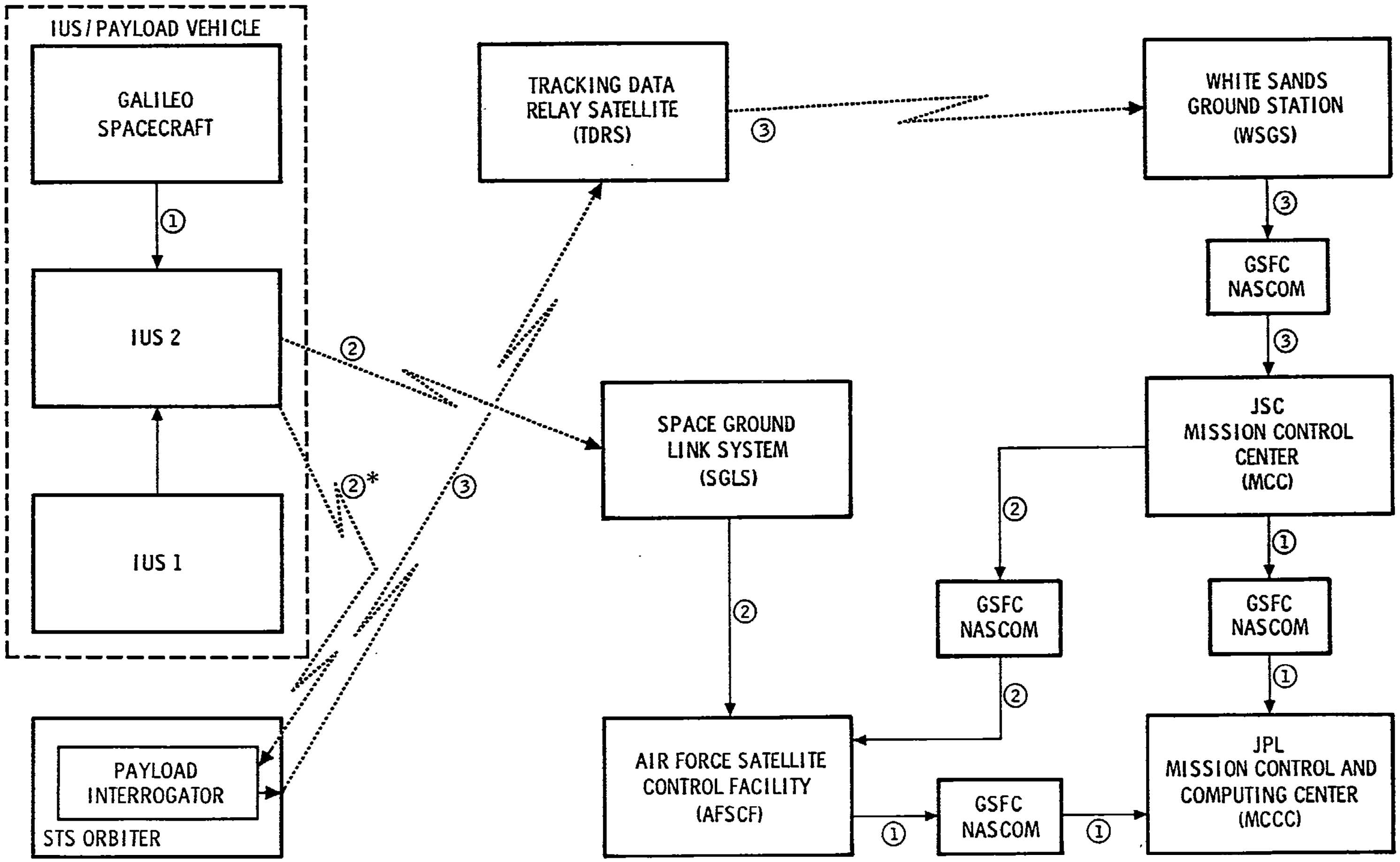


Fig. 6. Telemetry data flow in the Shuttle attached phase—Shuttle on-orbit phase



*AVAILABLE ONLY 20 KM FROM STS ORBITER

① GALILEO TELEMETRY (600 AND 1200 B/S)
② GALILEO/IUS TELEMETRY
③ SHUTTLE ORBITER DATA TELEMETRY

Fig. 7. Telemetry data flow in the Shuttle detached phase—IUS burn subphase

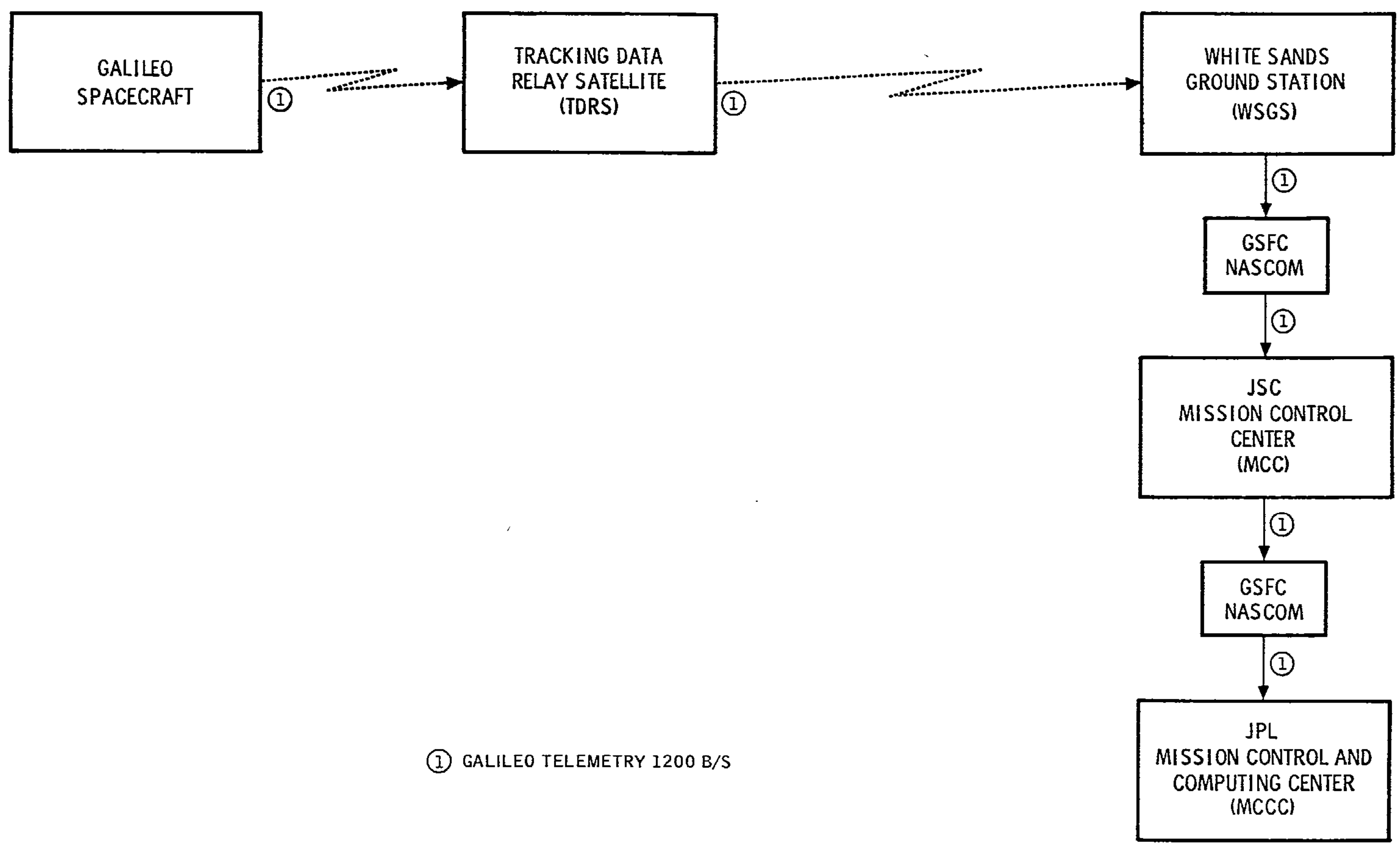


Fig. 8. Telemetry data flow in the Shuttle detached phase—spacecraft injection module burn subphase

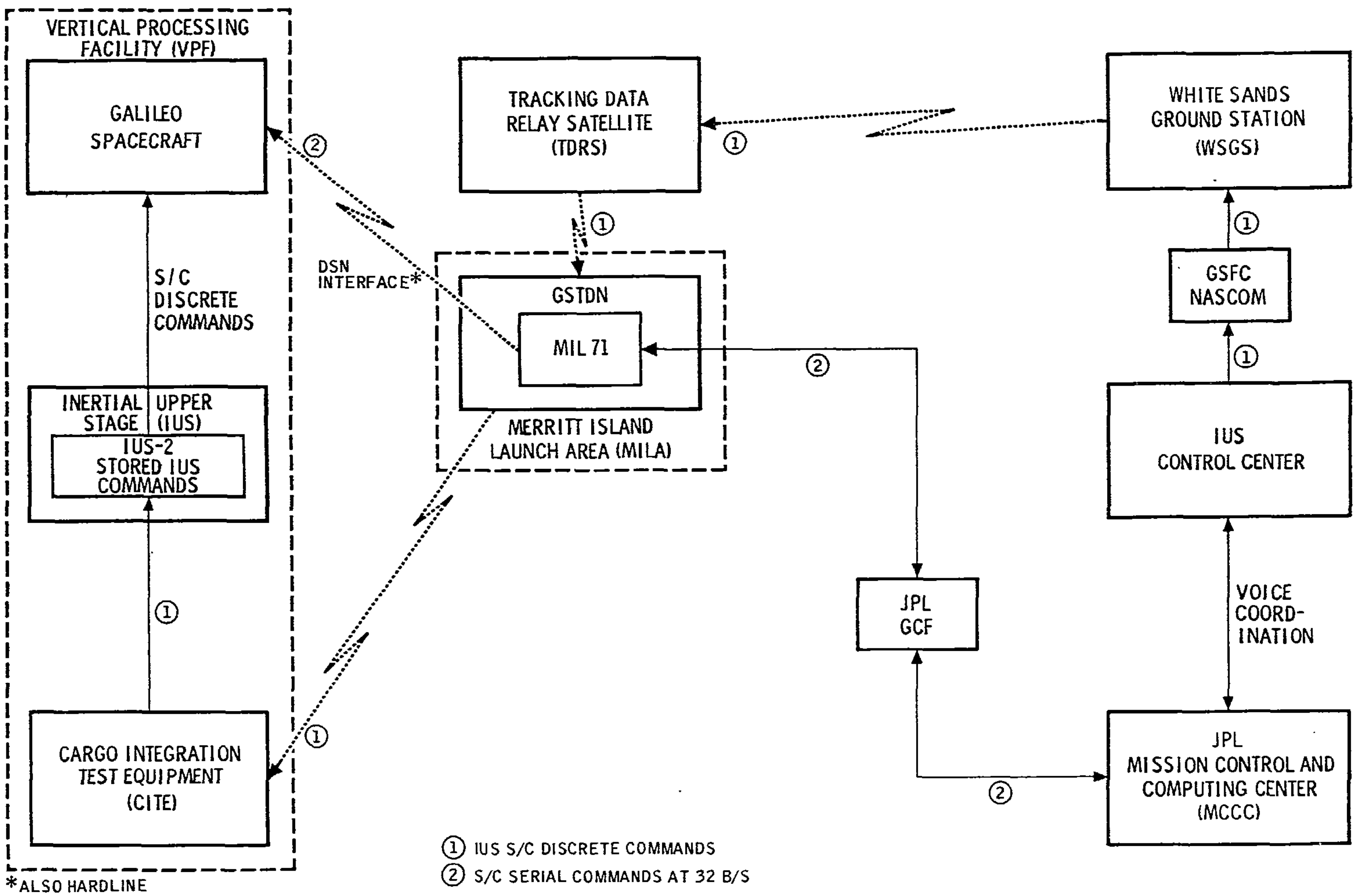


Fig. 9. Command data flow in the prelaunch phase—Vertical Processing Facility subphase

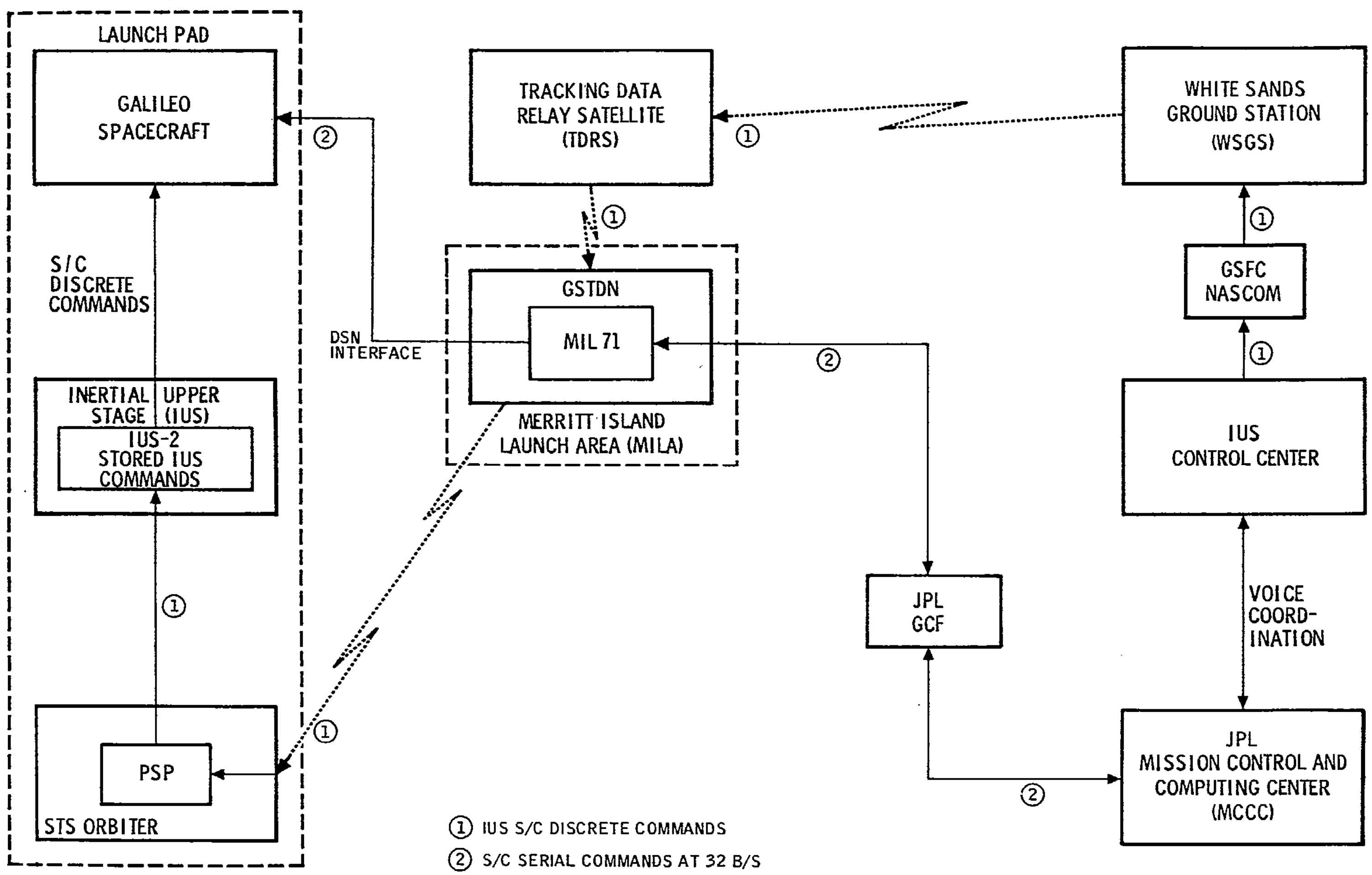


Fig. 10. Command data flow in the prelaunch phase—launch pad subphase

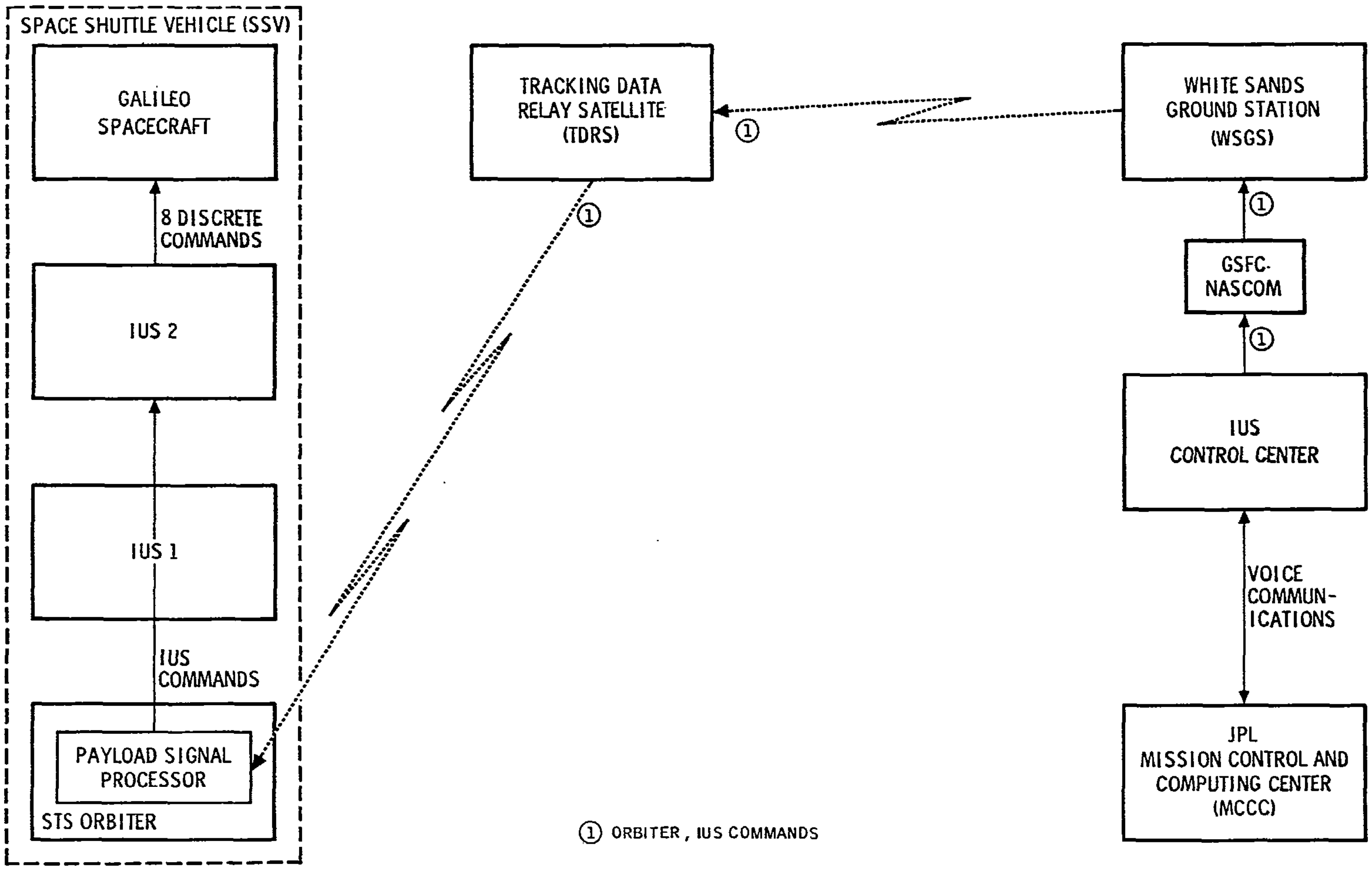


Fig. 11. Command data flow in the Shuttle attached phase—Shuttle on-orbit subphase

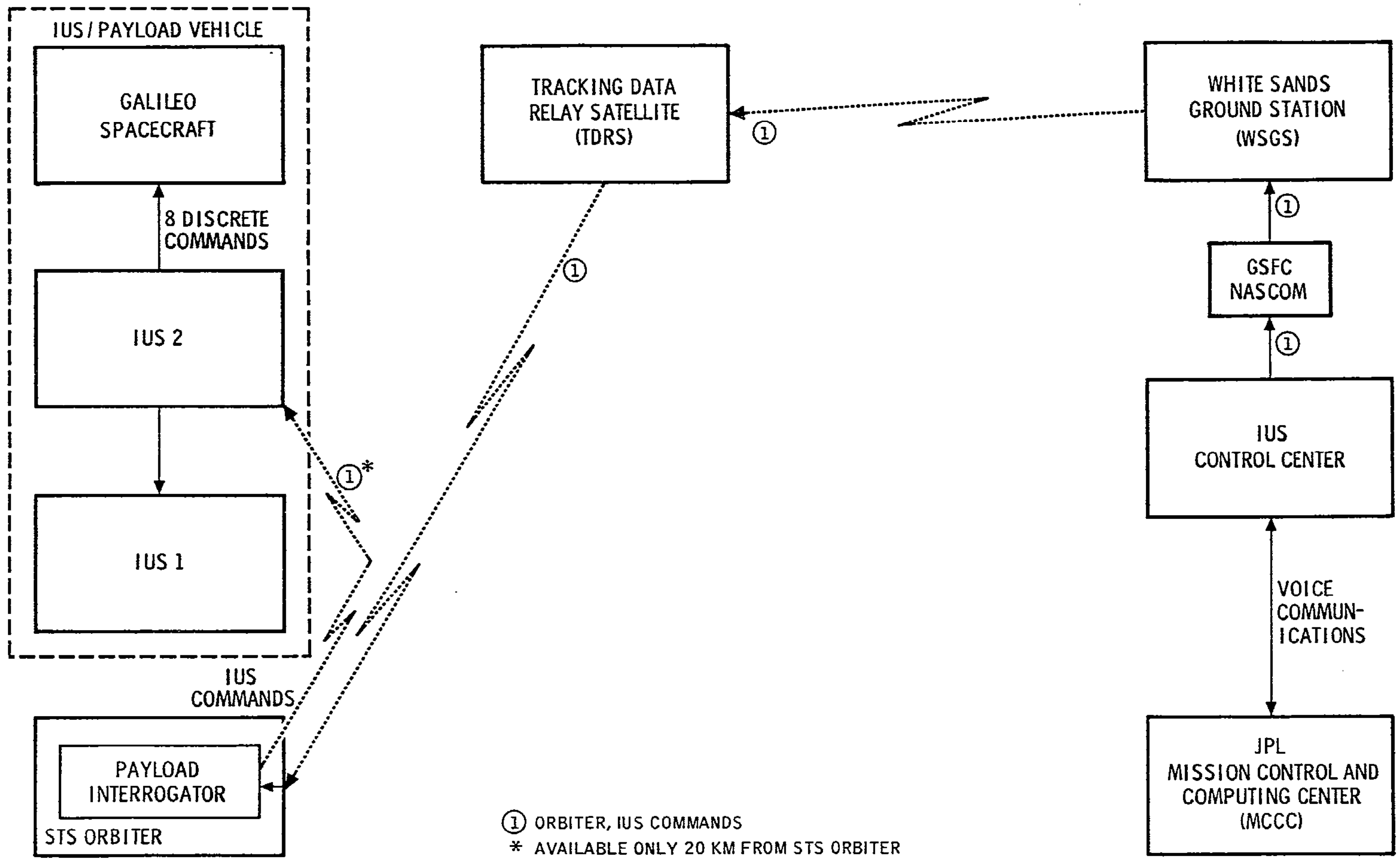


Fig. 12. Command data flow in the Shuttle detached phase—IUS burn phase