The 1986 Launch of the Galileo Spacecraft via the Space Transportation System

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Beginning with the Galileo spacecraft launch in 1986, 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 the planned 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 late May 1986, 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 the 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 post-launch period are identified, and telemetry and command data flow configurations are presented for each subphase. The Galileo mission sequence of events and data flow configurations here described can be considered typical of deep space launches planned for the Shuttle era.

The information here described was first presented in Ref. 2, under the assumption that the upper stage was to be the Inertial Upper Stage (IUS); this article now updates the information for the currently planned Centaur upper stage.

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 Lewis Research Center).

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 late May 1986 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. During all spacecraft testing at KSC, command and telemetry support will be provided via the DSN Facility (MIL 71) with operations control from the Mission Support Area (MSA) at JPL. 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 can 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 Centaur. Tests via the Merritt Island Launch Area (MILA) will be conducted to verify Space Shuttle end-to-end communications using the Cargo-Integration Test Equipment (CITE) to provide simulated Shuttle data interfaces. 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 30 days before launch, the spacraft 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. About four days before launch, the RTGs are re-installed in the spacecraft. Final end-to-end communications tests using MILA and Space Transportation System (STS) Tracking Data Relay Satellite (TDRS) communications links will then be conducted. These tests should last about two days. At their conclusion, the launch countdown will commence.

Figure 1 presents the nominal Galileo prelaunch sequence of events for a May 1986 launch.

B. Nominal Galileo Postlaunch Sequence of Events

Galileo launch mode telemetry will be available in near-real-time via the STS-TDRS communications link, from liftoff to Shuttle-Centaur separation. Based on the telemetry data, a decision to continue with the planned flight to Jupiter must be made by Launch plus 3 hours.

If a "go" decision is made, the Shuttle-Centaur separation should occur during the third Shuttle orbit, at about four hours after launch. During the more favorable periods of the launch window, the separation could be delayed until the fourth or the fifth orbit without jeopardizing the objectives of the Galileo mission. After separation, a Centaur S-band link can be used to route data between the spacecraft and Shuttle or TDRS. The maximum useful range of the Centaur to Shuttle link is 10 kilometers.

About 45 minutes after Shuttle-Centaur separation, the Centaur main engine will burn for approximately 10 minutes. After main engine cutoff (MECO), the Centaur will initiate a slow thermal roll of 0.1 rpm, and the Galileo spacecraft will start deployment of the RTG, science and magnetometer booms. The spacecraft transmitters will then be turned on to provide a downlink through TDRS just prior to Centaur-spacecraft separation. Centaur will turn the spacecraft to point 8 degrees to the earth side of the sun and will spin-up the spacecraft to 2.9 rpm. The spacecraft will then separate from Centaur, which will maneuver to avoid the same trajectory path as the Galileo spacecraft. The spacecraft transponder will now be the only means of exchanging data between the earth and the spacecraft.

Immediately after separation, the high-gain antenna will be deployed and the retro propulsion module (RPM) pressurized. During these events, DSN acquisition of the downlink will be established (approximately 15 minutes after Centaur-spacecraft separation). After RPM pressurization, the Galileo spacecraft will perform a sun acquisition (approximately one hour after Centaur-spacecraft separation).

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.

A. Prelaunch Phase

This phase starts with spacecraft assembly in the Spacecraft Assembly and Encapsulation Facility (SAEF), 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 phase are identified as:

(1) Spacecraft assembly and encapsulation facility.

(2) Vertical processign facility.

(3) Launch pad.

B. Shuttle Attached Phase

The 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 Centaur 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 Centaur spacecraft is placed outside the Shuttle vehicle, and proceeds through the Centaur burn and spacecraft-Centaur separation. This phase terminates with a successful DSN initial acquisition. Subphases during the Shuttle detached phase are identified as:

(1) Centaur burn.

(2) Post Centaur separation.

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

There are four major telemetry and two 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). Alternatively, 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 – Centaur

This path is for telemetry data only. Spacecraft telemetry is embedded in Centaur telemetry. An RF link is established from the Centaur to the TDRS. From TDRS, an RF downlink is established to WSGS. From there, the data is transmitted via DOMSAT to the GSFC NASCOM switching center, and thence through DOMSAT to the Centaur Payload Operations Control Center (POCC), at the Lewis Research Center (LRC). From LRC POCC, Galileo telemetry is stripped out and transmitted via GSFC NASCOM 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 Centaur telemetry data to the Shuttle Orbiter. From the 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 MCCC, Galileo telemetry is stripped out and transmitted via GSFC NASCOM to JPL MCCC. Alternatively, Centaur Galileo telemetry is transmitted via GSFC NASCOM to LRC POCC, where Galileo telemetry is stripped out and provided through GSFC NASCOM to JPL MCCC.

For command, the link begins with the LRC Centaur POCC, in conjunction with voice communication from JPL

MCCC. From the LRC POCC, the link is first to JSC MCC through GSFC NASCOM, then to WSGS through GSFC NASCOM, and finally RF to TDRS to the Shuttle Orbiter. From the Orbiter, the link is either hardline or RF (Centaur Shuttle Orbiter distance <20 km) to Centaur, and finally, to the Galileo spacecraft. For this mode, only a limited series of commands ("discrete commands") is possible.

Figures 3 through 11 illustrate the above data flow paths for the various launch subphases.

References

1. Khatib, A. R., Berman, A. L., and Wackley, J. A., "Space Shuttle Launch Era Spacecraft Injection Errors and DSN Initial Acquisition," *TDA Progress Report 42-64*, Jet Propulsion Laboratory, Pasadena, Calif., pp. 80-82, Aug. 15, 1981.
2. Berman, A. L., Larkin, W. E., and McKinney, J.C., "Deep Space Payload Launches via the Space Transportation System," *TDA Progress Report 42-70*, Jet Propulsion Laboratory, Pasadena, Calif., pp. 21-36, August 15, 1982.

Note Added During Publication

In December 1982, significant modifications were made to the Galileo launch support plan; primarily, these modifications involved locating the Centaur Payload Operations Control Center (POCC) at Kennedy Space Center (KSC) and performing the DSN initial acquisition prior to spacecraft-Centaur separation. The impact of these changes on the launch phase configurations and sequences of events will be described in a future article.

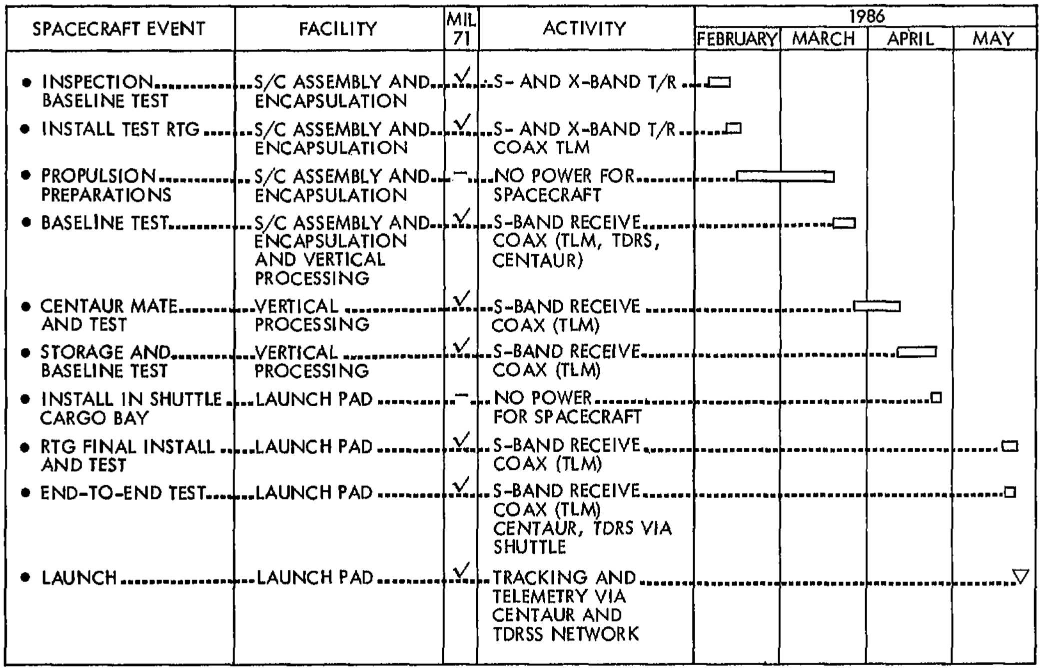
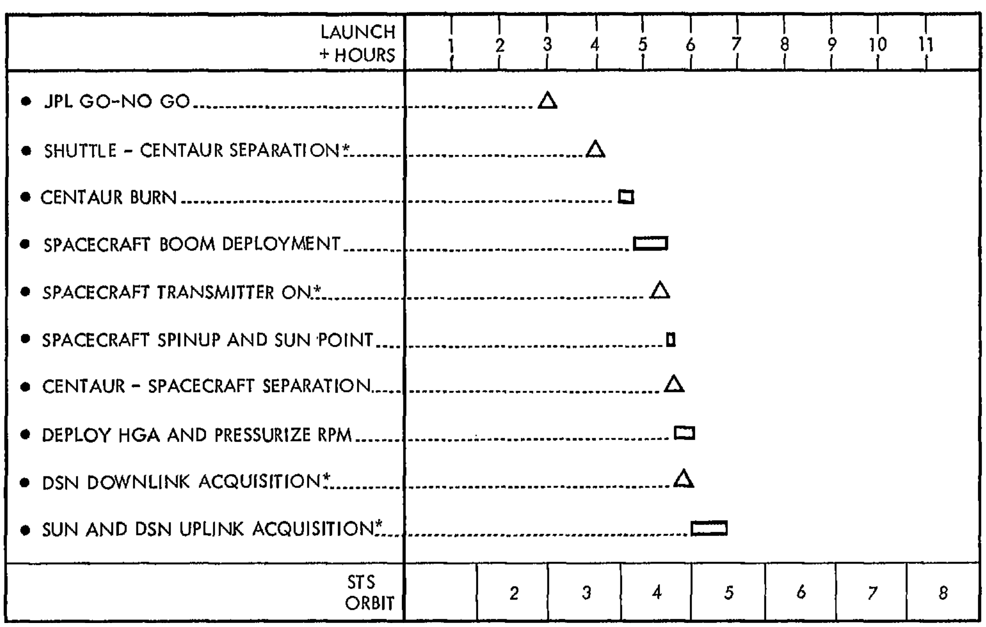
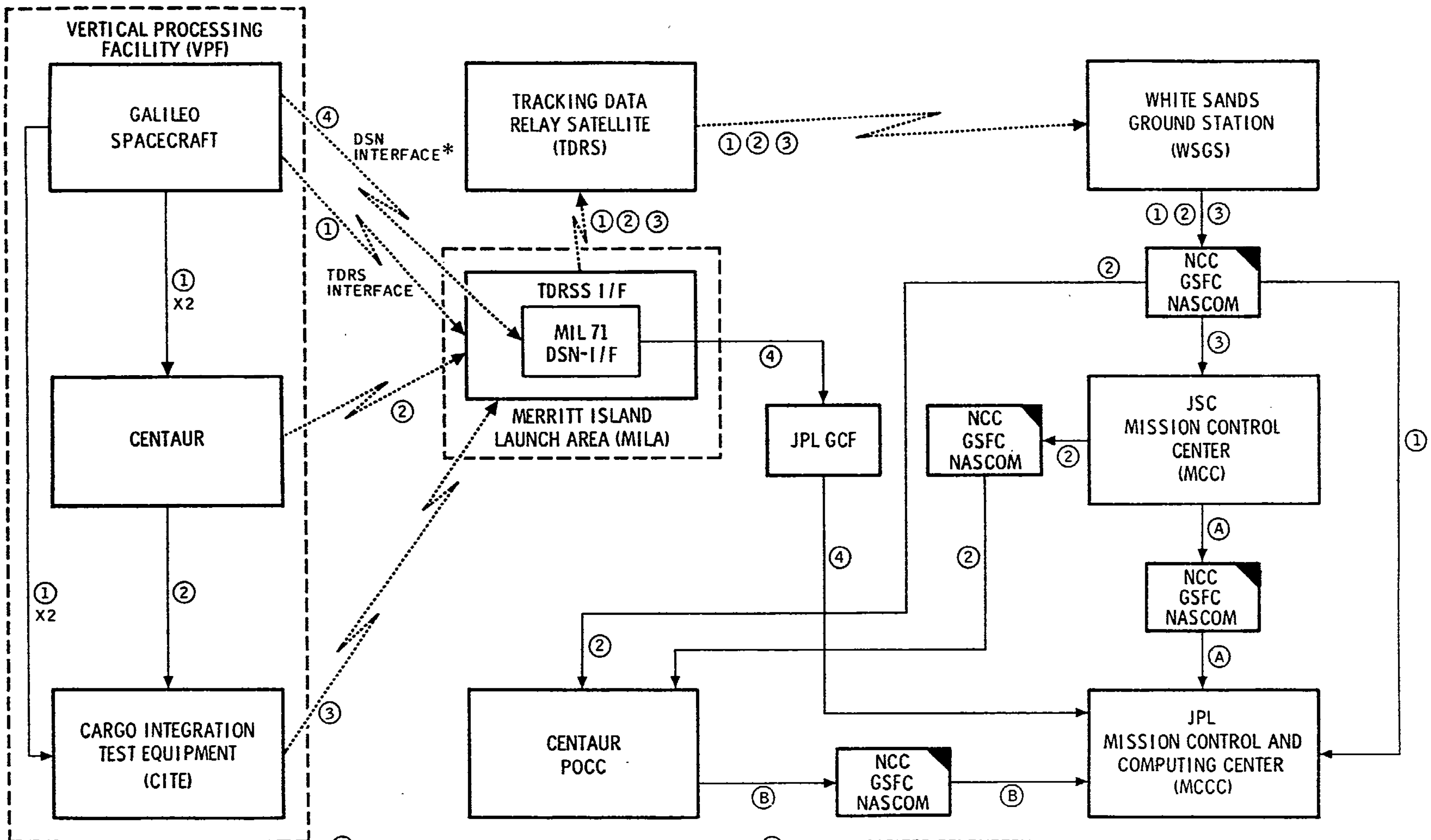


Fig. 1. Nominal Galileo prelaunch sequence of events for a May 1986 launch



* THIS SEQUENCE COULD BE DELAYED 1 OR 2 ORBITS

Fig. 2. Nominal Galileo postlaunch sequence of events for a May 1986 launch



*ALSO HARDLINE

X2 - REDUNDANT INTERFACES TO GLL SPACECRAFT

① GALILEO TELEMETRY (1200 B/S)

② GALILEO/CENTAUR TELEMETRY

◥ NCC-GSFC PERFORMS DATA ROUTING AND MESSAGE SWITCHING FUNCTIONS ONLY

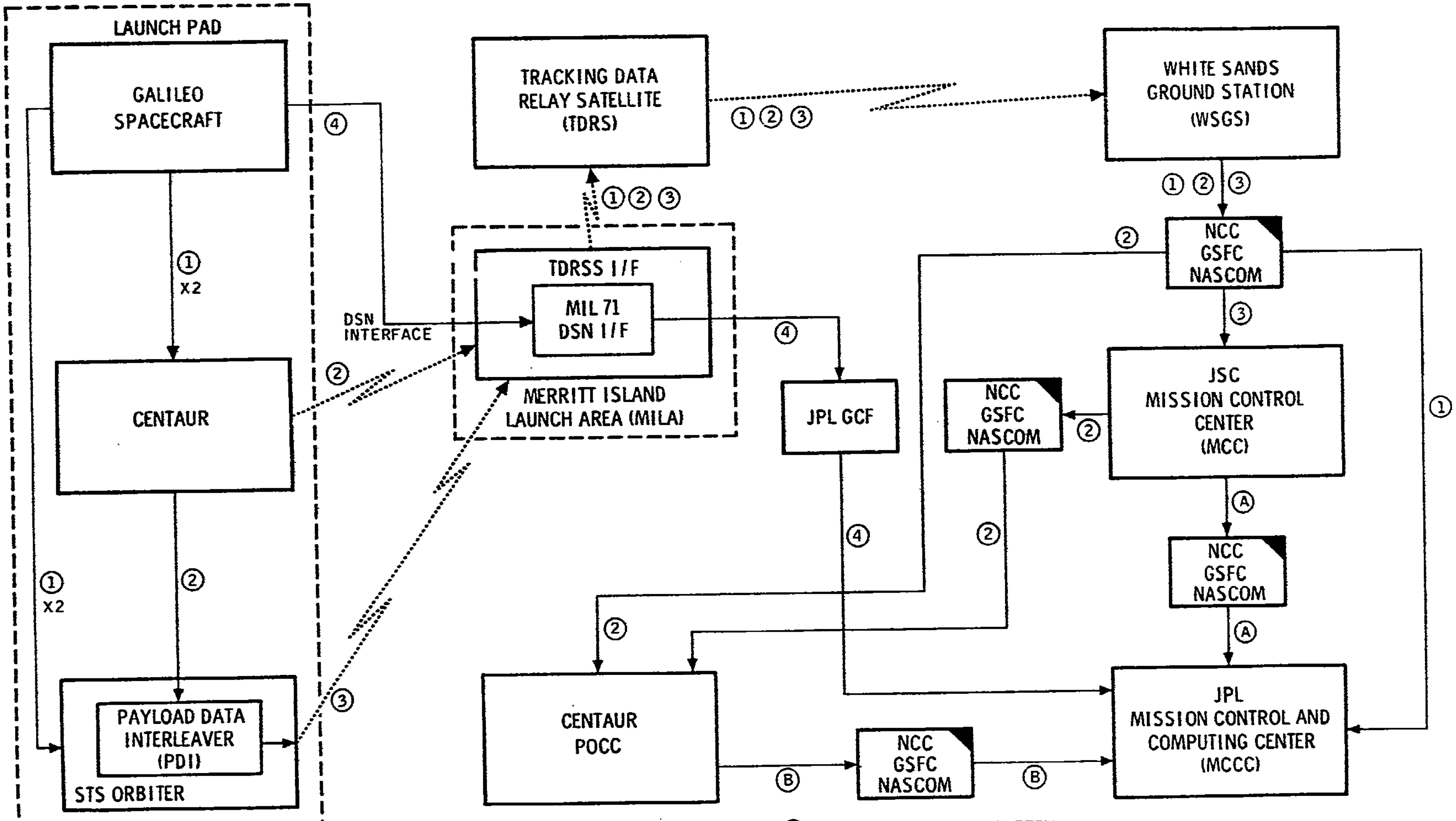
③ SHUTTLE ORBITER TELEMETRY

④ GALILEO TELEMETRY (≤ 115.2 KB/S)

Ⓐ EXTRACTED GALILEO (PDI LINK) TELEMETRY

Ⓑ EXTRACTED GALILEO (CENTAUR LINK) TELEMETRY

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



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④ GALILEO TELEMETRY (≤ 115.2 KB/S)

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

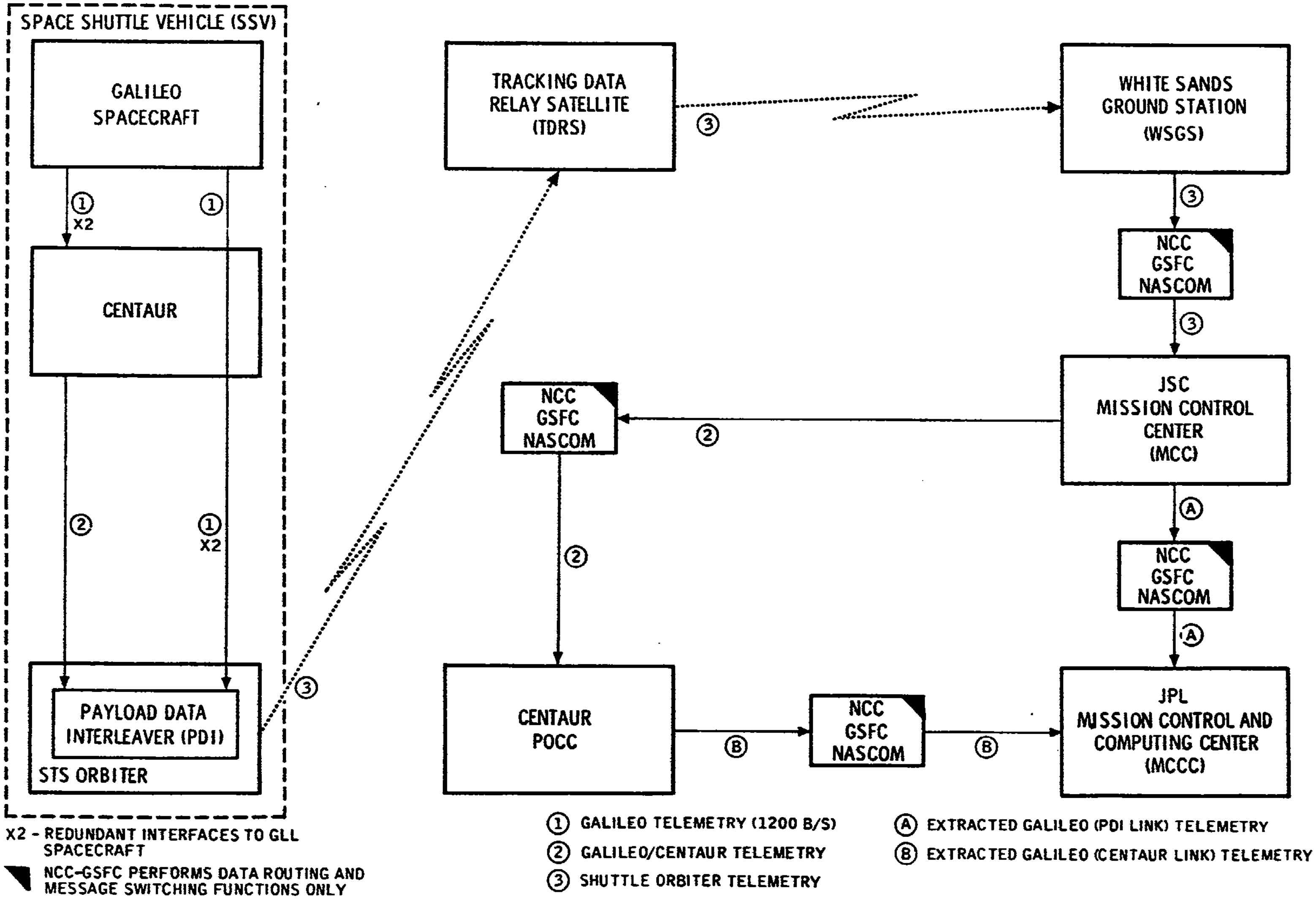

Fig. 5. Telemetry data flow in the Shuttle attached phase – ascent subphase

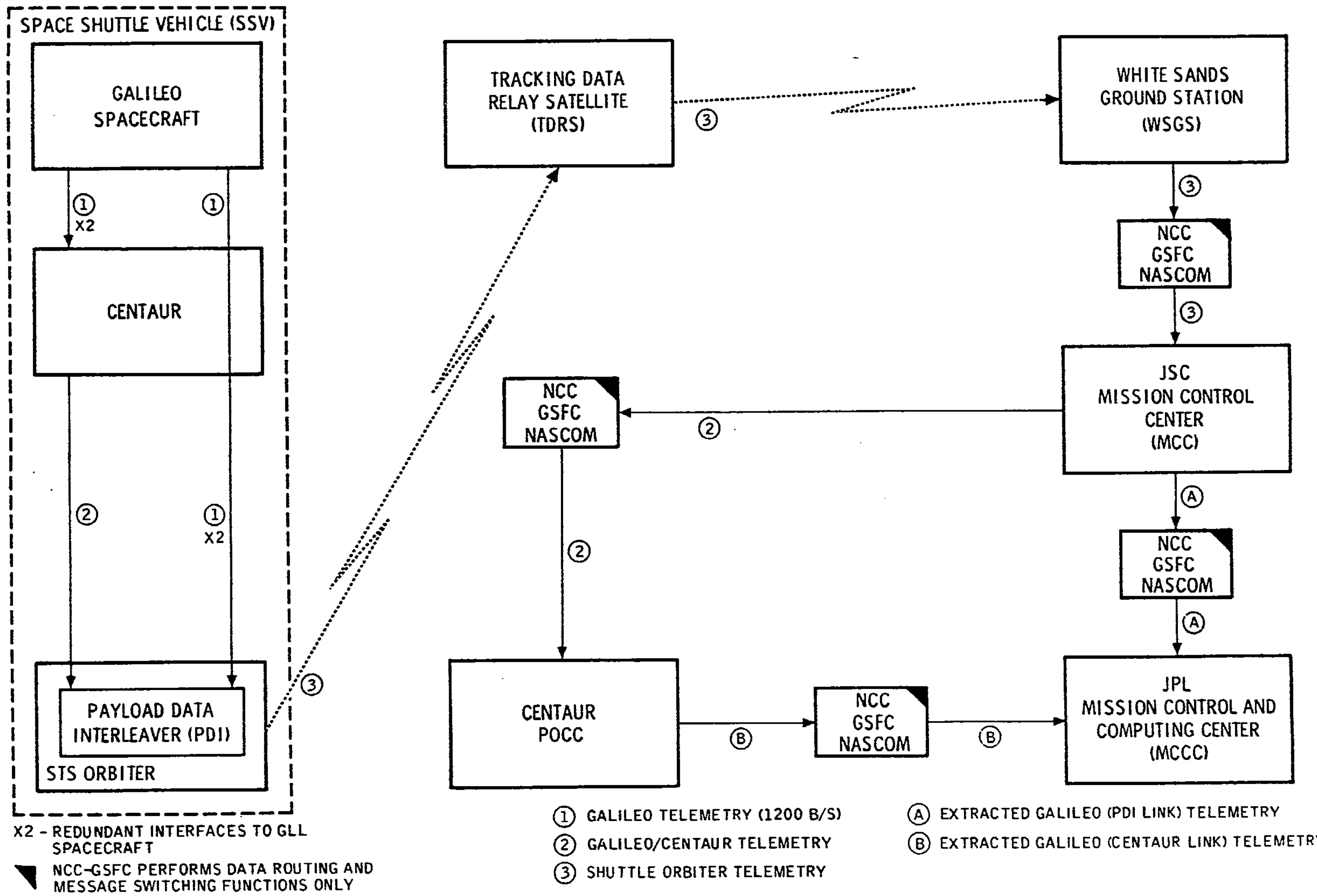

Fig. 6. Telemetry data flow in the Shuttle attached phase – Shuttle on-orbit subphase

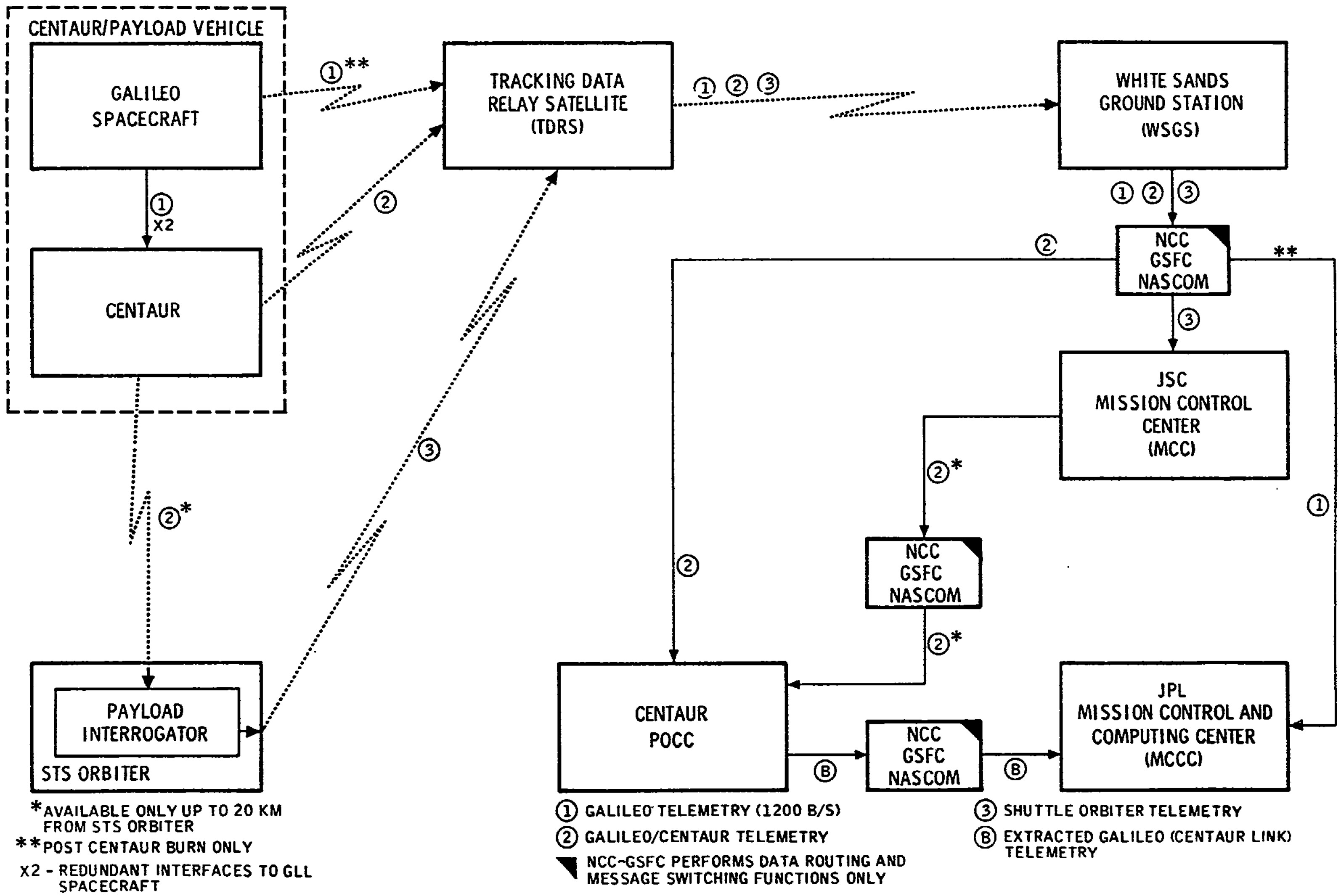

Fig. 7. Telemetry data flow in the Shuttle detached phase

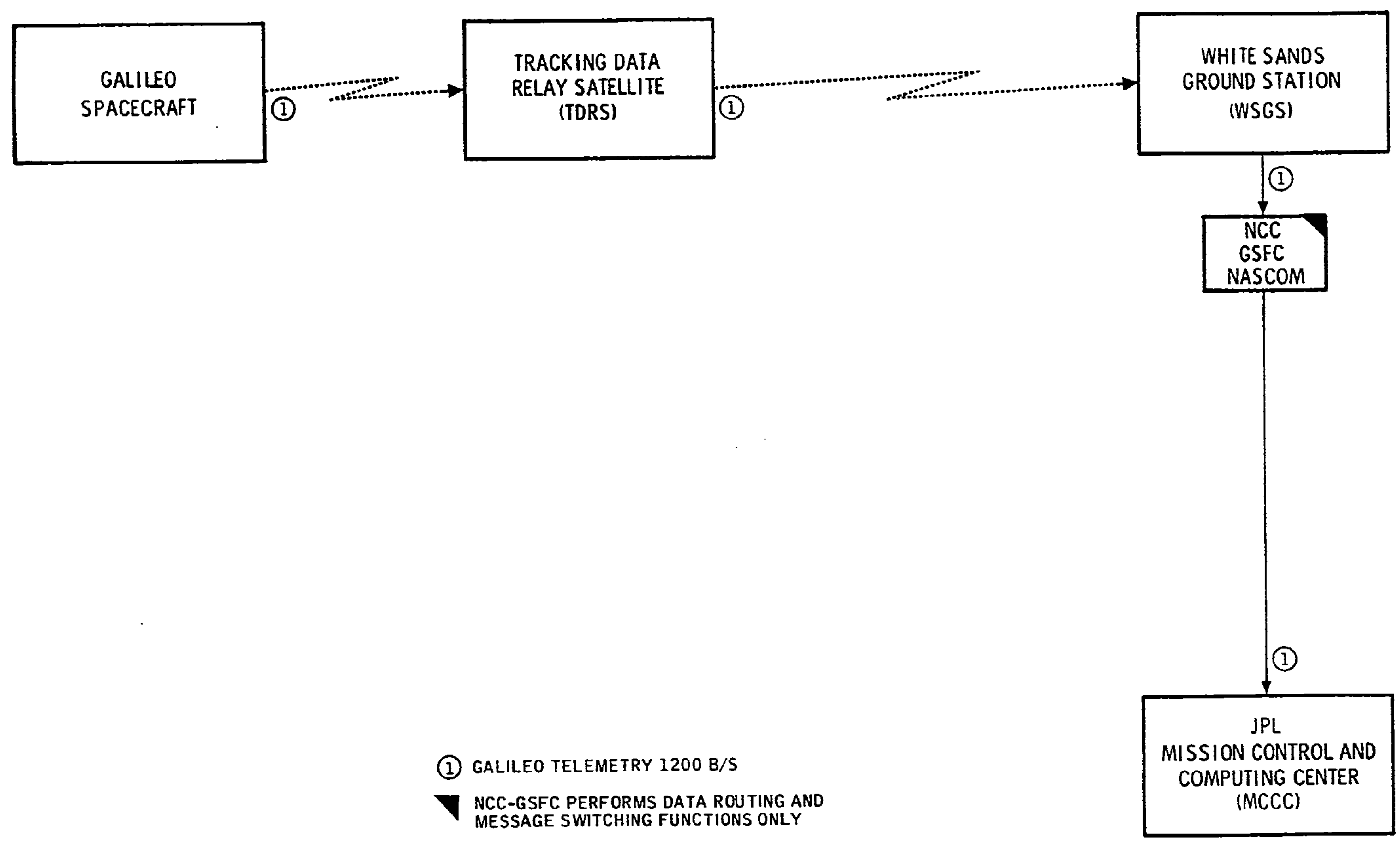

Fig. 8. Telemetry data flow in the Shuttle detached phase – post Centaur separation phase

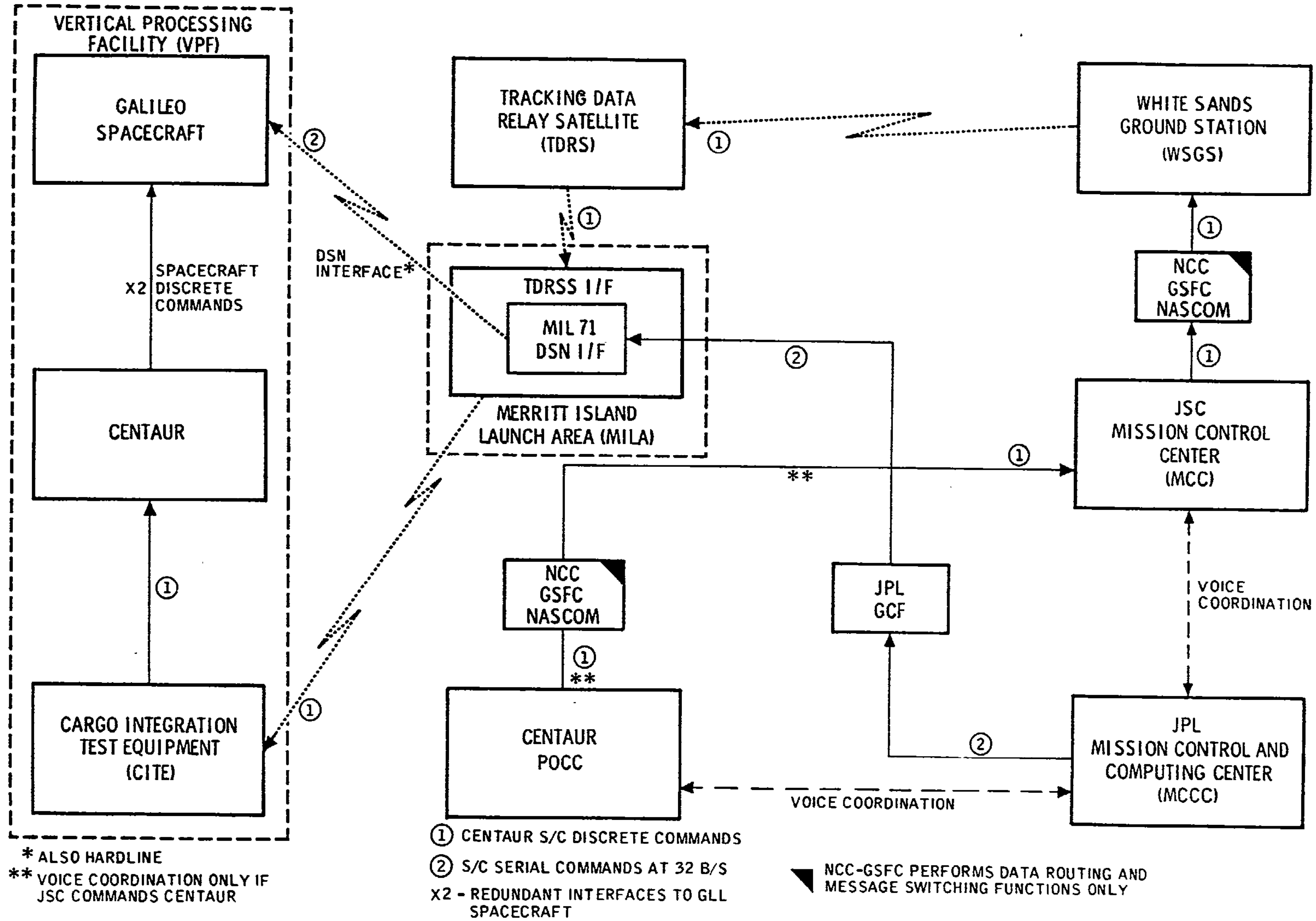

Fig. 9. Command data flow in the prelaunch phase – Vertical Processing Facility subphase

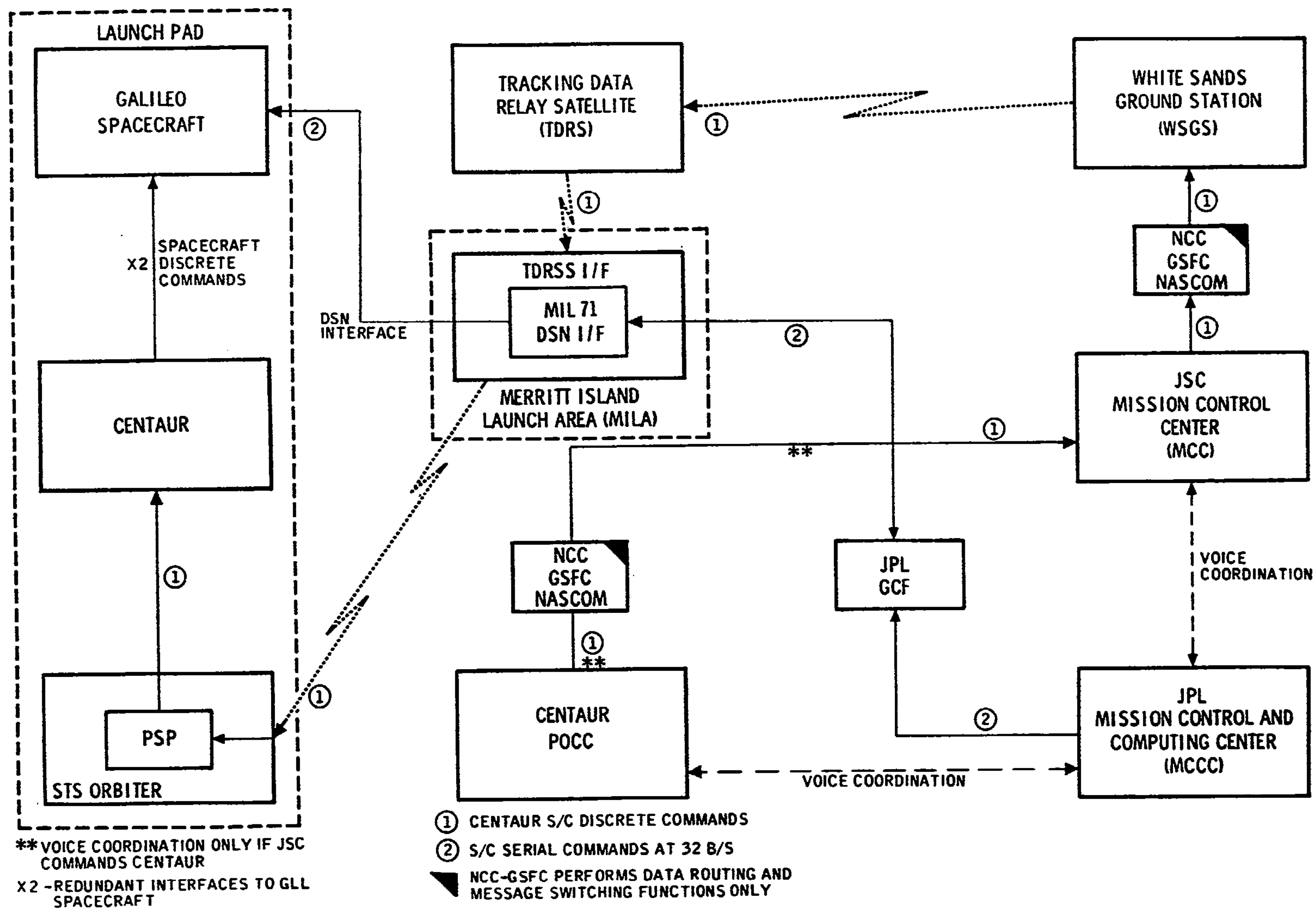

Fig. 10. Command data flow in the prelaunch phase – launch pad subphase

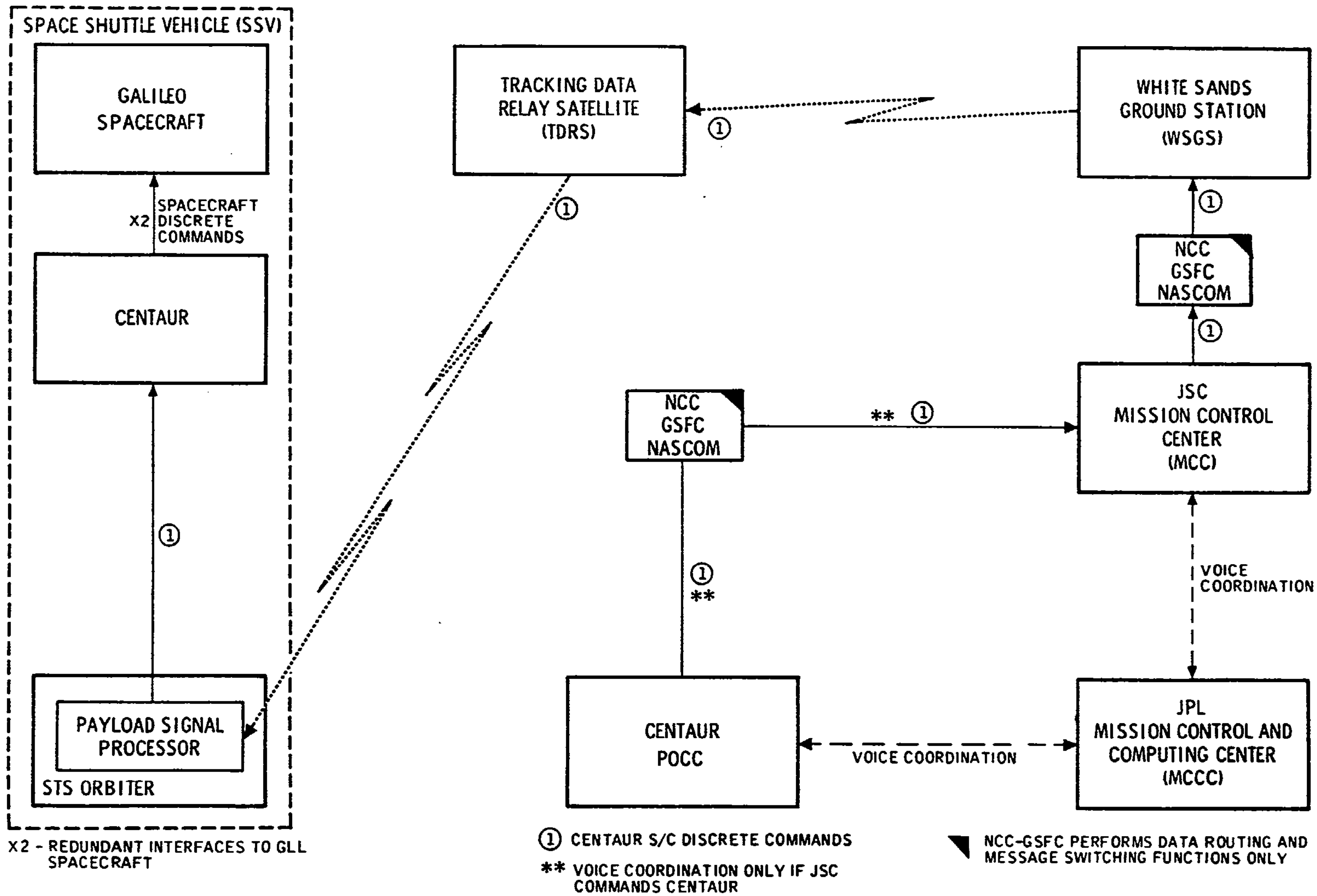

Fig. 11. Command data flow in the Shuttle attached phase – Shuttle on-orbit subphase