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Paper Session II-B - National Launch System Launch Operations

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NATIONAL LAUNCH SYSTEM LAUNCH OPERATIONS

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ABSTRACT

The National Launch System (NLS) is the nation's next generation family of launch vehicles, and is being jointly developed by NASA and the Air Force. The three vehicle classes, capable of placing 20Klb, 50Klb, and 80Klb into low earth orbit (LEO), will initially be launched between 2001 and 2004 from Kennedy Space Center (KSC) and Cape Canaveral Air Force Station (CCAFS). This paper describes the launch operations concepts currently envisioned for the NLS vehicles. Ground processing timelines, facilities, core stage processing options, launch support manpower estimates (as compared to the Space Shuttle), and new technologies will also be discussed. Launch processing costs will also be discussed as they relate to the total cost per flight of the existing Shuttle program.

TRAFFIC MODEL

The NLS program is planning for a maximum sustainable flight rate of 3 per year from KSC (with upto 8 STS flights), 10 per year from CCAFS, and 10 per year from Vandenberg Air Force Base (VAFB). The initial launch capability (ILC) for NLS vehicles from VAFB is under review, and VAFB operations will not be discussed. The vehicles are as follows: 1) NLS 1—when used with a Cargo Transfer Vehicle (CTV), is capable of placing at least 80Klb of useable payload in Space Station Freedom orbit (220 nmi circular, 28.5 deg. inclination), with an initial launch capability (ILC) of 2001[1] from KSC only; 2) NLS 2—capable of lifting 50Klb into a 80 X 150 nmi, 28.5 deg. orbit, with an ILC of 2001 from KSC and 2002 from CCAFS; 3) NLS 3—capable of lifting 20Klb into a 80 X 150 nmi, 28.5 deg. orbit, with an ILC of 2004 from CCAFS only. The Air Force plans to use a LO2/LH2 NLS upper stage (NLSUS) on its NLS 2 and NLS 3 vehicle launches from CCAFS and VAFB. A detailed description of all NLS vehicle flight hardware has been prepared by the Marshall Space Flight Center[2].

PROCESSING SCENARIO

The NLS program will require significant new and modified facilities at KSC and CCAFS. Figure 1 depicts the ground processing scenario for NLS 1 and NLS 2 vehicles in the 2002 timeframe. The NLS 3 vehicle will follow the same launch processing flow as the NLS 2 vehicle at CCAFS, beginning in 2004. The launch operations of the NLS vehicle will follow an "integrate-transfer-launch" (ITL) approach, as opposed to an "integrate-on-pad" (IOP) approach. STS and Titan III and IV program planners intended to use this ITL philosophy, but have resorted to a mixed ITL/IOP technique. The majority (70%) of STS and all Titan III and IV payloads are integrated with the vehicle on the pad.

The NLS payloads, upper stages, and shrouds will be integrated offline in an encapsulation or integration facility. The launch vehicle will be built-up on a mobile platform in a separate assembly facility. The encapsulated payload will then be mated with the launch vehicle in this assembly facility. Finally, the completely integrated vehicle will be moved to the pad, fueled, and launched. Therefore, the launch pad will become more of a "runway" and less of a processing facility.

PROCESSING FACILITIES

To achieve this ITL processing goal, KSC will require a new CTV Checkout Facility (CTVCF), Payload Encapsulation Facility (PEF), and Mobile Launch Tower (MLT). KSC will also need to modify highbay 2 or 4 in the Vehicle Assembly Building (VAB), LC-39A, and a firing room and launch processing system (LPS) software in the Launch Control Center (LCC). CCAFS will require even more new facilities, including a new launch pad,

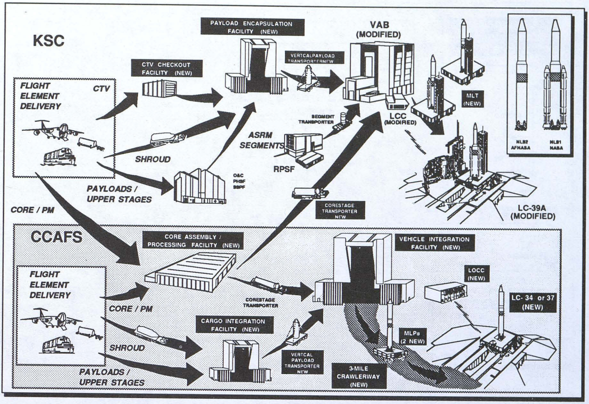

Figure 1. NLS Integrated Processing Scenario

Vehicle Integration Facility (VIF), Core Assembly and Processing Facility (CAPF), Cargo Integration Facility (CIF), two Mobile Launch Platforms (MLPs), Launch Operations Control Center (LOCC), crawler/transporter, and crawlerway. The cost of new and modified facilities at both launch sites totals more than $2.0 billion.

The NLS 1 and NLS 2 vehicles will utilize a common MLT for NASA launches from KSC. The CTVCF facility will only be used to support CTV processing for the NLS 1 vehicle, and the ASRM Rotation, Processing and Surge Facility (RPSF) will be used for STS and NLS 1 ASRM processing. The CAPF will be used to support core stage processing for <u>all</u> NLS vehicles at CCAFS and KSC. The NLS 1 core stage uses 4 STME sustainer engines. The NLS 2 vehicle uses 2 STME sustainer and 4 staged STME engines (6 total). LC-39A will be used to support STS, NLS 1 and NLS 2 launches. NLS program planners must assure that the eastern launch site (KSC and CCAFS) infrastructure is capable of supporting mixed fleet launches of NLS, STS, Titan, Atlas, and Delta launch vehicles.

<u>NLS 2 PROCESSING TIMELINES</u>

Preliminary conservative and goal-oriented NLS 2 launch processing timelines are depicted in Figures 2A and 2B, respectively. If current "conservative" launch processing techniques are used, the NLS 2 launch vehicle will take 47 days to process, assuming the encapsulated payload is ready on-demand. In this scenario, the <u>launch site</u> is primarily responsible for ensuring the quality and flight readiness of all delivered flight elements. The 47 day timeline includes 24 days for core stage checkout and testing in the CAPF; 4 days of core/MLT mate and 5 days of

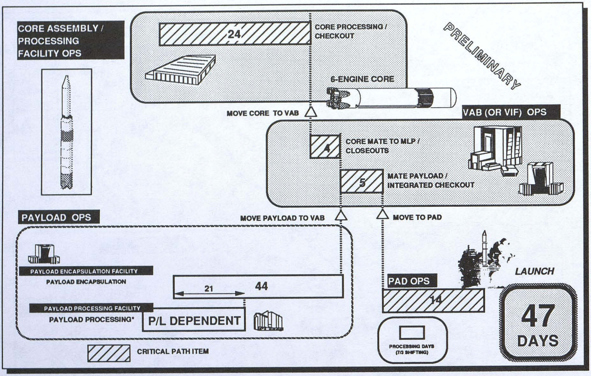

Figure 2A. NLS 2 Conservative Processing Timeline

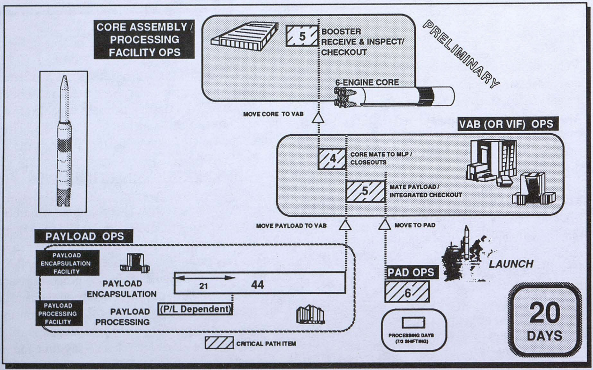

Figure 2B. NLS 2 Best Case Processing Timeline of encapsulated payload/launch vehicle mate and interface verification testing (IVT) in the VAB or VIF; and 14 days of launch pad operations. Forty-four days of payload encapsulation are allocated for Titan-derived trisector shroud buildup, payload and upper stage (optional) installation and servicing, shroud pyro installation, nosecone installation, and interface testing at the CIF or PEF.

The 24 days of core stage work includes receipt/inspection, MPS and STME leak checks, bus isolation, avionics, flight controls and STME flight readiness tests, staged STME separation pyro installation, and closeout. Deorbit/reaction control system (RCS) roll control system installation is optional. The 14 days of launch pad work includes MLT/Pad mate and validation, countdown demonstration test, core stage LO2 and LH2 purge, deorbit/RCS roll control system hypergol loading, ordnance installation, LO2 and LH2 loading, countdown, and launch.

The best-case NLS 2 processing time is 20 days, assuming the encapsulated payload is ready on-demand. In this "ship-and-shoot" scenario, the manufacturer is primarily responsible for ensuring the quality and flight readiness of all delivered flight elements. This 20 day timeline includes 5 days for core stage receipt and inspection in the CAPF; 4 days of core/MLT mate and 5 days of encapsulated payload/launch vehicle mate and interface verification testing (IVT) in the VAB or VIF; and 6 days of launch pad operations. Forty-four days of payload encapsulation are allocated for Titan-derived trisector shroud buildup, payload and upper stage (optional) installation, servicing, shroud pyro installation, nosecone installation, and interface testing at the PEF or CIF.

The 5 days of CAPF operations involves core stage receipt and inspection only. No core stage testing or assembly is performed (i.e., MPS and STME leak checks, flight readiness test, deorbit/RCS roll control system installation), since the stage is assumed "ready to fly" from the manufacturer. The 6 days of pad operations includes streamlined pad/MLT mate and validation, hypergol loading, LO2 and LH2 loading, terminal countdown and launch. Only time-critical, hazardous processing activities are performed at the pad in this scenario.

NLS 1 PROCESSING TIMELINES

Preliminary conservative and best-case NLS 1 launch processing schedules are shown in Figures 3A and 3B, respectively. The total processing times are similar since ASRM stacking and core/ASRM mate is on the critical path, not core processing and checkout.

The conservative 56 day schedule critical path is comprised of 24 days of ASRM segment stacking and joint leak checks on the MLT in the VAB, 13 days of core-to-ASRM mate and closeout in the VAB, 5 days of encapsulated payload/launch vehicle mate and IVT, and 14 days of launch pad operations. All VAB operations for NLS 1 are analagous to STS VAB activities. ASRM stacking is the same for both vehicles, NLS 1 core/ASRM mate is similar to STS ET/ASRM mate, and NLS 1 payload/vehicle mate is similar to STS orbiter/vehicle mate. The 14 days of pad activities are the same as described above for NLS 2, with added activities for CTV and ASRM hydraulic power unit hypergol loading, and ASRM range safety ordnance installation. No deorbit/RCS roll control system hypergol loading is required for NLS 1.

Not included in the 56 days are 23 days of ASRM segment RPSF operations, 21 days of core checkout at the CAPF, and 44 days of cargo encapsulation. ASRM segments and encapsulated payload are assumed to be ready on-demand. The 21 day conservative core checkout time is shorter than the NLS 2 conservative 24 day core checkout time because the NLS 1 core stage has 4 sustainer STMEs, and the NLS 2 core stage has 6 STMEs, with quick disconnects for inflight staging of 4 STMEs.

The 44 days of cargo encapsulation includes at least 21 days of Titan-derived bisector shroud and strongback buildup, shroud pyro installation, pay-

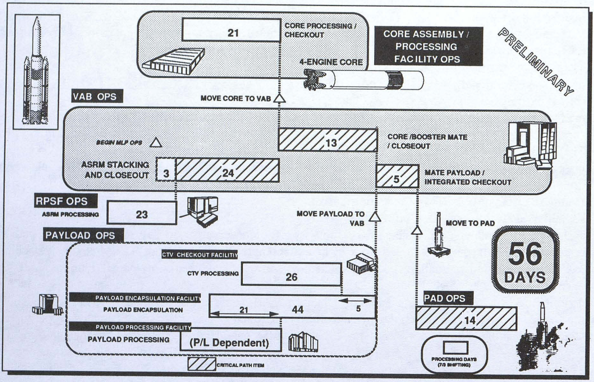

Figure 3A. NLS 1 Conservative Processing Timeline

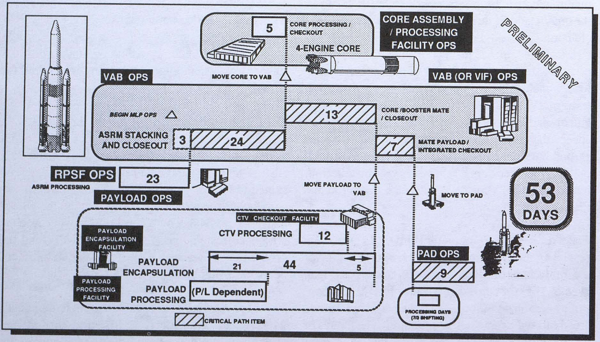

Figure 3B. NLS 1 Best Case Processing Timeline load installation and servicing, CTV installation, nosecone installation, and interface testing at the CIF or PEF. Twenty six days have been allocated in the conservative scenario to process the hypergolic CTV. The CTV is assumed to be reusable (recovered and returned post-mission via STS). In this scenario, the CTV is returned to KSC with hypergol residuals in the propellant tanks and lines. Seventeen days are spent deservicing and purging the CTV hypergolic fuel and oxidizer at the existing STS hypergol maintenance facility (HMF), and 9 days are spent performing reaction control system (RCS), avionics, and integrated CTV systems tests at the CTVCF. These CTV checkout activities are analagous to those performed on the STS orbital maneuvering system (OMS) and forward RCS pods. The CTV is then integrated with the cargo carrier at the PEF or CIF during the final 5 days of payload encapsulation.

The best-case 53 day schedule critical path includes 24 days of ASRM segment stacking on the MLT and 13 days of core-to-ASRM mate and closeout in the VAB, 7 days of encapsulated payload/vehicle mate and IVT, and 9 days of pad operations. Pad operations include MLT/pad connect and validation, hypergol loading, ordnance installation, cryogenic LO2 and LH2 load, terminal countdown and launch. For the streamlined pad flow, the CTV is assumed to be loaded with hypergols offline, and core stage TVC battery installation is performed in the VAB. All payload functions at the pad are assumed to be worked in parallel with launch vehicle pad operations. Processing a hypergolic-fueled vehicle in the PEF and VAB is a hazardous operation that presents major concerns to KSC Safety.

Not included on the NLS 1 best-case critical path are 5 days of core stage checkout at the CAPF (ref. NLS 2 best-case timelines), 23 days of ASRM segment RPSF operations (above), and 44 days of payload encapsulation at the PEF or CIF (above). Twelve days of CTV processing are required in the best-case scenario. This assumes the CTV arrives "clean" at KSC. CTV reaction control system, avionics, and integrated CTV systems tests are performed at the CTVCF, then the CTV is integrated with the cargo carrier at the PEF or CIF during the last 5 days of payload encapsulation.

CORE STAGE ASSEMBLY

The NLS family core stages are currently baselined to arrive at the launch site CAPF pre-integrated; the STME engines, sustainer and booster (NLS 2 only) thrust structure and propulsion systems (referred to as "propulsion module"), core tank, and forward and aft skirts will be assembled at the Michoud Assembly Facility (MAF). This core stage will take between 5 and 24 days to checkout at the launch site, depending on whether the manufacturer or launch site is primarily responsible for ensuring the quality and flight readiness of the delivered flight element.

Figure 4 depicts some of the options for core stage assembly at the CAPF, as well as the program pre-integrated core stage baseline. Option 1 assumes the 4-6 STMEs, propulsion module, core tank, and skirts are checked-out separately and integrated at the CAPF. The Option 1 scenario involves 50 days of core stage processing. These 50 days of CAPF processing includes 22 days of parallel STME and propulsion module checkout, 17 days of parallel core tank checkout and STME-propulsion module mate, and 16 days of core tank-propulsion module mate and integrated core stage checkout.

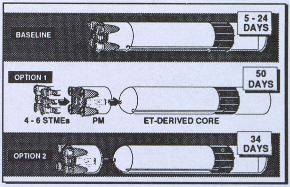

Figure 4. Core Stage Assembly Options

Option 2 assumes the STMEs and propulsion module arrive as one unit, and the core tank arrives as a separate unit. The Option 2 core stage takes 34 days to assemble at the CAPF. These 34 days include 21 days of propulsion module checkout and 17 days of core tank checkout, in parallel, and 16 days of core tank-propulsion module mate and integrated core stage checkout.

Since core stage assembly is required at the CAPF for Options 1 and 2, the launch site will be responsible for assuring the quality and flight readiness of the hardware. This results in a significant increase in launch site testing (with associated GSE and access platforms) and longer timelines than the 5 day best-case scenario. However, less assembly will be required at the manufacturer in these scenarios.

Several criteria need to be carefully evaluated and costed before selecting the NLS program's most efficient core stage assembly option. These criteria include the following: 1) manufacturer assembly and checkout requirements; 2) launch site assembly and checkout requirements; 3) duplication of checkout at the launch site; 4) avionics architecture; 5) mission flexibility, and; 6) capability to evolve to a recoverable core stage propulsion/avionics module.

PROCESSING MANPOWER

Estimates of NLS launch processing manpower have been made by analogy with STS flight 36, excluding all "manned" systems and thermal protection system orbiter activities. The manpower estimates include technicians, engineers, quality control, safety, and others directly supporting launch vehicle ground operations. These estimates are shown in Figures 5A and 5B. SRB buildup, stacking, and SRB/ET mate activities apply directly to the NLS 1 vehicle. Orbiter/vehicle mate and IVT (integrated VAB operations) apply directly to NLS 1 and NLS 2 encapsulated payload/vehicle mate and IVT. Pad operations were ratioed by number of days on the pad for NLS 1 and NLS 2 versus STS-36, assuming leveled manloading. CTV/upper stage processing is analagous to STS OMS and forward RCS pod processing, STS cargo bay integration is analagous to NLS cargo encapsulation, and STS ET, SSME, and MPS "boattail" processing is analagous to NLS core stage operations.

		(BEST CASE)	
ELEMENT	STS-36	NLS 1	NLS 2
SRB BUILDUP	20,000	20,000	—
SRB STACKING	33,488	33,488	—
ET STAND-ALONE	15,092	—	—
ORBITER	212,583	—	—
ET (OR CORE) / SRB (OR ASRM) MATE & CLOSEOUT	37,292	37,292	—
VAB INTEGRATED OPS	10,655	10,655	10,655
PAD INTEGRATED OPS	77,652	19,968	13,311
CTV / UPPER STAGE	—	6,911	6,911
CARGO ELEMENT	—	14,386	14,386
CORE STAGE	—	7,840	7,840
TOTAL MANHOURS	406,762	150,540	53,103

PRELIMINARY

Figure 5A. NLS / STS Flight Element Processing

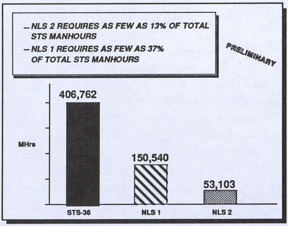

Figure 5B. Total Processing Manhour Comparisons

Preliminary results indicate the NLS 1 vehicle requires 37% the manpower support of an STS flight, and NLS 2 requires only 13% the manpower support of STS for each launch site flow. NLS 1 requires 150,540 manhours, NLS 2 requires 53,103 manhours, and STS-36 required 406,762 manhours. These totals reflect the best-case NLS processing timelines. STS manpower is appreciably higher because most of the STS hardware is recovered or refurbished, and includes manned systems processing.

RECURRING COSTS PER FLIGHT

The STS and NLS 2 vehicle recurring cost/flight breakdowns are illustrated in Figure 6. Launch operations at KSC comprise 25% of the STS cost/flight, and 7.4% of the NLS 2 planned cost/flight. Mission operations at the Johnson Space Center (JSC) account for 20% of the STS cost/flight, but have not yet been evaluated for NLS. Flight hardware accounts for approximately 36% of the STS cost/flight and 92% of the NLS cost/flight.

A third-level breakdown of the STS cost/flight WBS, also illustrated in Figure 6, shows that only 5.3% of the total STS cost/flight is incurred by "hands-on" Shuttle launch vehicle processing (5.3% = 25% KSC launch operations x 63% Shuttle processing contract (SPC) x 33% Shuttle hands-on processing). Logistics, support operations (program, technical, LPS, systems engineering), facilities operations and maintenance (O&M), propellants, base operations, and payload operations account for the majority (78%) of the STS launch site infrastructure cost/flight.

OBSERVATIONS

Several new technologies are currently being developed with the goal of increasing the operability of the NLS vehicles. These technologies include laser-initiated pyrotechnics (replacing current pyrotechnics), electromechanical actuators powered by batteries (replacing hydraulics powered by hydrazine-fed auxiliary power units), and vehicle health management for flight and ground elements. These technologies should result in some level of increased launch processing efficiency.

However, hardware launch processing has been shown above to account for only about 5% of the STS recurring costs[3]. Furthermore, this 5% fraction contains many mechanical and transportation-intensive functions which will be minimally impacted by new technologies. To reduce total launch operations costs, the NLS program will need to address, control, and reduce the 78% of "hands off" launch site infrastructure cost per flight.

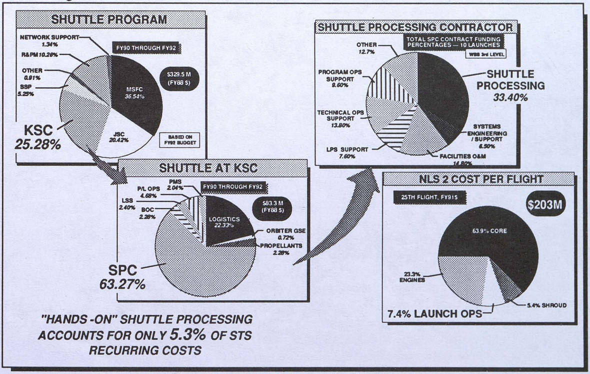

Figure 6. STS and NLS 2 Recurring Costs Per Flight

The key challenge for NLS program will be to: 1) reduce the hardware costs which comprise over 90% of the NLS cost/flight, and; 2) streamline the entire launch vehicle infrastructure, not just the launch site. This will require improved methods of quality control/assurance without mandating manpower-intensive oversight, and improved methods of hardware and software procurement, launch and mission planning services procurement, and cost reduction incentives.

1 NLS Program System Requirements Document, Version 5.0, 15 Nov 1991

2 NLS Launch Vehicle Level III System Requirements Document, MSFC-RQMT-1978, 13 Dec. 1991

3 Facility O&M is half as large as "hands on" Shuttle processing costs