

Comprehensive Engineering Analysis of Aerospace Ascent Checklists: From Space Shuttle STS-107 to Artemis SLS

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In the high-stakes environment of human spaceflight, the transition from Earth's surface to low Earth orbit (LEO) represents one of the most dynamic and risk-intensive phases of a mission. To manage the immense complexity of vehicle systems, aerodynamic pressures, and propulsion requirements, aerospace agencies like NASA utilize a rigorous documentation framework known as the **Flight Data File (FDF)**. Central to this framework is the **Ascent Checklist**—a document that serves as the definitive operational guide for both the flight crew and ground controllers during the critical minutes between ignition and orbital insertion.

The Architecture of the Flight Data File (FDF)

The Flight Data File is not a single document but a modular library of procedures, data, and reference materials tailored for specific mission phases. For the Space Shuttle Program (SSP), these were codified under Joint Space Center (JSC) designations, such as **JSC-48005-107** (specific to STS-107) or **JSC-48003-II** (Generic Ascent Pocket Checklist). The FDF is engineered for high-stress usability, featuring laminated pages, tabbed sections for rapid access, and a standardized symbology to convey urgency and system status.

Core Components of the Ascent FDF

- **Ascent Checklist (Main)**: Contains the primary nominal and contingency procedures from T-minus 9 minutes through Main Engine Cutoff (MECO).
- **Ascent Pocket Checklist (APCL)**: A condensed version designed to be worn on the pilot's or commander's leg, providing immediate access to critical abort maneuvers and time-sensitive system reconfigurations.
- **Abort Summary Cards**: Graphical representations of abort boundaries, defining when specific emergency landings (RTLS, TAL, or ATO) are physically viable based on velocity and altitude.

Technical Analysis of the Ascent Phase: Step-by-Step Mechanics

The ascent of a heavy-lift vehicle like the Space Shuttle or the **Space Launch System (SLS)** is governed by the principles of orbital mechanics and atmospheric physics. The checklist guides the crew through several distinct regimes, each requiring precise interaction with the **General Purpose Computers (GPCs)** and **Guidance, Navigation, and Control (GNC)** systems.

1. Pre-Launch and Ignition (T-9 Minutes to T-0)

During this phase, the checklist focuses on the transition of the Orbiter or SLS to internal power. For the Space Shuttle, this involved the **Auxiliary Power Units (APUs)**, which provided hydraulic pressure for the Main Engine (SSME) gimbals and control surfaces. The checklist requires verification of the **RS-25** engine start sequence, where four engines (on SLS) or three (on STS) must reach 100% rated thrust before the Solid Rocket Boosters (SRBs) ignite.

2. First Stage: Max Q and SRB Separation

As the vehicle accelerates, it encounters **Max Q** (maximum dynamic pressure). The checklist dictates a "throttle bucket"—reducing engine thrust to roughly 65-72% to minimize structural loads. Once the SRBs reach burnout (approx. T+2 minutes), they are jettisoned. The crew must monitor the "NEG RETURN" boundary, which signifies

the point beyond which a **Return to Launch Site (RTLS)** abort is no longer possible due to excessive velocity.

3. Second Stage: Liquid Propulsion and Trajectory Shaping

Post-SRB separation, the vehicle relies entirely on its liquid-fueled engines. The checklist transitions to **GNC OPS 102** or **OPS 103**. The crew monitors the **"DROOP"** and **"PRESS TO ATO"** boundaries. If a single engine fails, the checklist provides the specific "Abort to Orbit" (ATO) procedures to ensure a stable, albeit lower, orbit can be achieved.

Technical Comparison: STS vs. SLS (Artemis) Ascent Systems

The evolution from the Space Shuttle to the Artemis SLS highlights significant shifts in thrust-to-weight ratios and checklist automation. The following table compares key metrics identified in the **Artemis SLS Green Run Checklist** and historical STS FDF data.

Feature/Metric	Space Shuttle (STS)	Space Launch System (SLS)	Operational Impact
Primary Engines	3 x RS-25 (SSME)	4 x RS-25	Increased initial lift capacity for deep space payloads.
Maximum Thrust	~1.2 Million lbs (Liquid)	2 Million lbs (Liquid)	Enhanced thrust allows for larger TLI (Trans-Lunar Injection) stages.
Checklist Format	Physical FDF / Hardcopy	Electronic Flight Bag / Integrated Display	Reduces crew workload and physical mass in the cockpit.
Abort Logic	Manual Trigger (Complex)	Highly Automated (LAS)	The Launch Abort System (LAS) provides safer crew extraction.

Emergency Procedures and High-Altitude Bailout

One of the most critical sections of the Ascent Checklist involves the **Bailout Procedures**. In the post-Challenger era, NASA implemented a telescopic escape pole and specific survival protocols for the crew. The checklist (referenced in **JSC-48003**) provides a specific sequence for egress at altitudes below 50,000 feet MSL.

The "Green Apple" and Oxygen Supply

When the checklist indicates a transition to **Bailout Mode**, the crew must perform the following actions:

1. Close and Lock Visor: Essential to maintain pressure and protect the face from high-speed windblast.
2. Activate Independent Oxygen: This is achieved by pulling the "Green Apple" handle on the suit. This provides 10 minutes of emergency oxygen, allowing the crew member to breathe during the descent through the stratosphere and troposphere.
3. Depressurize Cabin: The checklist directs the crew to manually vent the cabin pressure to equalize with the outside environment before opening the side hatch.

Mathematical Foundations of Ascent Monitoring

Flight controllers and crew use the checklist to verify mathematical milestones during ascent. One key formula is the calculation of **Remaining Delta-V** (ΔV_{rem}) required to reach MECO targets. This is expressed through the Tsiolkovsky Rocket Equation:

$$\Delta V_{rem} = v_e \ln \left(\frac{m_{initial}}{m_{final}} \right) - \frac{F}{m}$$

Where:

- v_e is the effective exhaust velocity ($I_{sp} * g_0$).
- $m_{initial}$ is the mass at the current checklist milestone.
- m_{final} is the target mass at MECO.

If the GPCs detect that the vehicle's actual acceleration ($a = F/m$) does not align with the checklist-predicted **P-I (Post-Insertion)** values, the crew must execute "DROOP" or "NEG RETURN" procedures immediately to prevent a

sub-orbital trajectory.

Case Study: STS-107 Flight Data File (JSC-48005-107)

The **STS-107 Ascent Checklist** (Revision A, March 25, 2002) provides a unique look at mission-specific tailoring. Unlike generic checklists, this document included precise **No Comm Mode** boundaries. In the event of a total loss of communication with Mission Control (Houston), the crew used the "**NEG RETURN (104)**" and "**PRESS TO ATO (104)**" cards to make autonomous decisions regarding their ascent trajectory. This level of autonomy is a cornerstone of aerospace safety engineering, ensuring that even in "dark" scenarios, the crew has a roadmap to orbital stability or safe abort landing.

Checklist Configuration Control

The 107 FDF illustrates the rigorous versioning required in aerospace. With **Rev. A** and **Final** designations, every change—no matter how minor—undergoes a Flight Data File Change Request (FDFCR) process. This ensures that the 230+ pages of the Ascent FDF are synchronized with the **Mission Control Center (MCC)** software and the **Shuttle Mission Simulator (SMS)** training runs.

The Role of Simulation in Checklist Mastery

For modern enthusiasts and trainee engineers, software like **Space Shuttle Ultra (SSU)** and **Orbiter** provides a high-fidelity environment to practice these procedures. These simulators replicate the GNC OPS 101/106 transitions found in the **JSC-48003-II** manual. Users must manually manage the OMS-2 maneuver coast and transition to the **Post-Insertion Checklist**, which involves opening the payload bay doors and configuring the radiators—a critical step to prevent the Orbiter from overheating once the heat of ascent is trapped by the vacuum of space.

Operational Challenges and Troubleshooting

Checklists are not merely instruction manuals; they are diagnostic tools. During the **Artemis SLS Green Run**, the checklist was used to manage the longest-duration burn of the RS-25 engines on a test stand. When sensors detect an anomaly (e.g., a hydraulic leak or an engine controller failure), the checklist provides a "**Fault Tree**" approach:

- Identification: Which sensor triggered the alarm (e.g., Fuel Pre-Burner Pressure)?
- Isolating: Can the component be isolated without affecting the entire engine cluster?
- Decision: Does the anomaly require a MECO (Main Engine Cutoff) or can the mission continue at a reduced throttle?

Common Failure Modes in Ascent

Historical data indicates that the most common ascent challenges involve **Sensor Ambiguity** and **Transducer Failures**. The Ascent Checklist mitigates this by requiring "cross-checking"—verifying a reading on **CRT 1** against the backup **GNC** displays before taking an irreversible action like an engine shutdown.

The sophisticated nature of the Ascent Checklist, whether for the legacy Space Shuttle or the modern SLS, underscores the necessity of structured, verified procedures in the conquest of space. These documents transform the chaotic energy of millions of pounds of thrust into a controlled, predictable climb toward the stars. As we move into the Artemis era, the principles established in the JSC Flight Data Files—rigorous documentation, clear abort boundaries, and meticulous crew training—remain the foundation of orbital safety. The ascent checklist is more

than a list of tasks; it is the technical manifestation of decades of engineering lessons, designed to bring crews through the fire of launch and into the silence of orbit.

Baca Juga (Artikel Terkait)

- [The Comprehensive Guide to Amateur Aerospace Engineering and DIY Space Exploration](http://123caramba.com/guide-to-amateur-aerospace-engineering-diy-space-exploration.pdf)

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