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Advanced Launch Technology Life Cycle Analysis Using the Architectural Comparison Tool (ACT)

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March 2015

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Contents

Figures

Tables

1 INTRODUCTION

1.1 Purpose

The purpose of this document is to report the results of life cycle technology impact comparisons conducted by Kennedy Space Center's Engineering and Technology Directorate (KSC/NE) in fiscal year 2014 (FY14) for the Advanced Launch Technologies Impact Assessments (ALTIA) in cooperation with Langley Research Center (LaRC) and its Vehicle Analysis Branch (VAB).

1.2 Scope

The document covers the results of architectural comparisons for the nanolauncher and *Skylon* technology concepts based on the Affordability Comparison Tool (ACT) prototype.

1.3 Authority

The ALTIA activity was conducted for NASA's Space Technology Mission Directorate in coordination with NASA Langley Research Center (LaRC) and the Air Force Research Laboratory (AFRL) at Wright-Patterson Air Force Base (WP-AFB), Dayton, Ohio. The analysis work was performed under NASA WBS 662122.04.06.01, while supporting tool development and techniques documented were supported by NASA KSC's Engineering and Technology Directorate. For more information on ACT, refer to NASA Tech Briefs article, February 2014.

1.4 Background

In FY14, NASA's Space Technology Mission Directorate (STMD) Game Changing Development (GCD) Program investigated two technology areas in the ALTIA activity. The first would enable new markets in dedicated *nanolaunchers*; that is, launchers whose payload is very small and devoted solely to delivering *CubeSat*-sized payloads that would otherwise be restricted to secondary accommodation on missions that use a much larger class of launch vehicle (the state of the art). The second area investigated was the *Skylon* concept in support of a NASA Langley task agreement with AFRL. In 2014 the AFRL and NASA engaged in a Cooperative Research and Development Agreement (CRADA) between the U.S. government and Reaction Engines, Ltd. (REL), Oxfordshire, England, to assess the potential of certain advancements in air-breathing rocket propulsion, in turn enabling advanced aeronautical and single-stage-to-orbit (SSTO) concepts. ALTIA offered its life cycle analysis and ground segment expertise as part of the technical evaluation.

These technology pursuits are explored for the benefit of NASA's science community, as well as providing commercial entrepreneurs with new technology options for conducting activities in the space environment. With this in mind, the second phase of NASA's Nanolauncher Technology Impact Assessments pursues the objectives and path laid out for the following NASA Technology Areas (TAs):

- TA-01, Launch Propulsion Systems
- TA-11, Modeling, Simulation, Information Technology and Processing
- TA-13, Ground and Launch Systems Processing

1.5 Summary of Findings by KSC Engineering and Technology Integration Branch

Throughout the history of NASA, KSC technologists have desired to make life cycle outcomes more visible during the early concept and technology selection phases. Experienced in ground systems design supporting state-of-the-art spaceflight systems, as well as in spaceflight test, maintenance, and business operations, they have recognized that different design and technology choices, among different system and subsystem functions, will affect the life cycle profoundly. The Advanced Launch Technology Impact Assessments (ALTIA) effort brought together research center vehicle and systems analysts and KSC expertise in life cycle analysis, systems engineering, and technology integration.

In FY14, ALTIA examined cost drivers and whether technology investments could dramatically affect the life cycle affordability, productivity, and availability. The team reviewed advanced avionics as an enabler of greater affordability and availability for small-sat/CubeSat payload customers.

<u>Finding #1 – Minimize the infrastructure and use the system at a higher flight rate</u>
Achieving a launch cost at or below $2M per flight is within the realm of the possible, but requires a higher delivery pace than so far achieved (at least five or six per year), and some method to offset the fixed cost burden. After materials and other direct charges are accounted for, the total labor versus output must be carefully monitored and controlled to achieve these low levels. The largest cost driver is fixed recurring production costs, with flight rate being a cost driver at less than one launch every other month.

<u>Finding #2 – Pursue focused nanolauncher technologies and design approaches, such as integrated avionics and a three-stage nanolauncher.</u>
These two examples enable simpler infrastructures, shorter production times, and greater flight rate capability. Of the technologies the team had time to pursue, advanced avionics can reduce recurring cost by ~20%, as well as improve launch rates. However, advances in avionics that do not reduce the number of procured and installed avionics components do not realize significant cost and productivity benefits. A wider technology portfolio would be more effective in improving life cycle characteristics. A three-stage NL001 configuration (perhaps one with solids on the lower stages topped with a very small liquid upper stage) should achieve similar reductions,

<u>Finding #3 – “Express Lanes” and “Flex Lanes” for Nanolaunchers can better organize life cycle costs to support the industry.</u>
Consideration should be given to separating some of the dedicated small-sat delivery infrastructure—both production and operations. Specifically, delivery of payloads needing routine, low-cost, highly available service should be separated from other nonroutine activities.

Second, the KSC team reviewed the *Skylon* concept by Reaction Engines, Limited (U.K.) that envisions using air-breathing/rocket propulsion combinations in a single engine unit to enable horizontal takeoff/horizontal landing (HT/HL) single-stage-to-orbit (SSTO) transportation service in the future.

Finding # 5 – Findings relative to a Skylon quick-look life cycle assessment (separately controlled attachment)

New capabilities emerged from the ALTIA activities in 2014. First, the foregoing results were obtained using a newly developed Functional Systems Breakdown Structure (F-SBS). It was collaboratively developed and documented by LaRC and KSC ALTIA team members to derive a common architectural definition of the flight and ground systems for both system performance and life cycle analysis. The F-SBS allows simultaneous definition of flight and ground elements, subsystems, and technology components. Further, a comprehensive catalog of ground segment functions, to the same level of definition as the flight segment, was created for the F-SBS. Refinement activities continue.

Finding # 6 –Functional System Breakdown Structure (F-SBS) that includes a wider scope of the architecture is needed (see Section 4)

Finally, several general design techniques that are offered in this report for improving the life cycle characteristics of architectural concepts are noted for creating more effective conceptual designs.

Finding # 7 – General design principals and techniques observed (see Section 5)

2 COMPARING TECHNOLOGY IMPACTS ON NANOLAUNCHER LIFE CYCLES

During the latter half of FY13, a small LaRC/KSC team of system analysts was tasked to look at nanolauncher activities with the intent of discovering particular investment opportunities for NASA to pursue—should any be found. As part of this task, the prototype KSC Architectural Comparison Tool (ACT) was used in making nanolauncher life cycle comparisons. Results of those comparisons are provided in this section.

Section 2.1 provides background information on small dedicated launchers. Explored are activities and payload products being delivered and conceived of being delivered. Also examined are the existing rideshare capabilities of the space delivery market, and government and entrepreneurial prospects in this field.

2.1 Nanolauncher Introduction and Technical Approach

The first phase of the effort involved familiarizing the team with the miniaturized (small) satellite delivery market, including ongoing NASA and commercial efforts. It also involved setting up a systems analysis and life cycle analysis context for comparing different technical approaches to the dedicated nanolauncher design problem, and the effects that targeted technology investments could have on this advancing spaceflight market segment.

Miniaturization technology advancements have enabled small, inexpensive satellites that perform useful functions. The primary method for delivering these payloads into low Earth orbit (LEO) is through a “rideshare” opportunity (as a secondary payload), limiting access to the orbital space environment. As a result, small launch vehicles sized for and dedicated to delivering small satellites (a small number of CubeSat-sized devices, for instance) are under development by various commercial and government interests.

During the assessment task in Phase I, the LaRC/KSC team explored the viability of various design approaches in meeting dramatically low flight costs (on the order of $1M–$2M per flight, or less), and more particularly what, if any, technologies require investment to enable very low launch costs that would be competitive with equivalent rideshare/secondary payload prices. Potential customers would come from commercial, academic, civil government, as well as national security/DoD market segments.

The following task objectives were aimed at getting answers to certain questions:

a. Identify primary cost drivers for small launch vehicles.

b. Identify technology and concept opportunities to significantly improve launch costs and availability.

c. Determine the feasibility of achieving the goal of <$2M per launch.

The KSC Systems Integration Branch ran two sequential comparisons with the aid of an architectural comparison capability under development (the prototype Affordability Comparison Tool, or ACT).

Section 2.2 describes the setup of the first comparison, which was of the historical Scout launch vehicle program with modern nanolauncher vehicle concepts. The vehicle information was provided to KSC by NASA LaRC (Section 2.2.1 and Section 2.2.2). The purpose of the first comparison run was to understand the cost drivers across the life cycle and across recurring operations and infrastructure functions, for which ACT would be well suited, despite its developmental nature.

Section 2.3 summarizes and discusses the four primary results from running Comparison 1 with ACT.

Section 2.4 discusses potential improvement strategies to pursue with the limited civil service-only resources and time available. With Comparison 1 providing a better understanding of the performance, cost, and productivity drivers; the inter-center team chose the integration of advanced technologies into nanolauncher systems as the most appropriate strategy to pursue for NASA space technologists—particularly since the sponsor of ALTIA is NASA’s Space Technology Mission Directorate (STMD).

Section 2.5 describes the setup of the second comparison, as a consequence of the Comparison 1 results and the improvement strategies chosen for the second phase of the nanolauncher study. This examined the baseline four-stage all-solid NL001 concept provided by LaRC with an advanced integrated avionics version of the concept that used far fewer components.

Section 2.6 documents and discusses two more primary results from Comparison 2 relative to technology investments in nanolauncher systems.

Section 2.7 draws six conclusions from the results of the two nanolauncher life cycle comparisons, while Section 2.8 documents three specific findings relative to architectural design focus and life cycles of the nanolauncher segment of the space economy.

2.2 Comparison 1: Identify and Quantify Cost Drivers Relative to Actual Program

2.2.1 Scout Historical Launch Vehicle (Scout)

The team searched for a known system with documented data that could be used in a comparison of their designs. The desired parameters were (1) flight element, subsystem, and component/assembly design, (2) flight performance, (3) production costs, unit costs, and launch site operations costs at all locations, and (4) actual system utilization (i.e., flight rate). Availability of these parameters was critical to the requested analysis. Such data was available for the Scout launch vehicle (Figure 1). This broad performance, production, and operations capture tells the story of launch cost at a scale the team wished to convey for nanolaunchers—and key elements of this story were found in NASA's historical accounting of its Scout Launch Vehicle Program.

Conveniently, NASA's Scout Launch Vehicle Program documented a great deal of this information in two volumes.[1] The team began an analysis on several fronts in an effort to set up a disciplined set of comparisons anchored on the Scout information. Further, the Langley team settled on the D1 configuration as having the most useful and relevant information.

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[1] NASA Contractor Report 165950, *Scout Launch Vehicle Program, Final Report*, Phase VI, by Abraham Leiss, Contract NAS1-16520, NASA Langley Research Center, Hampton, Virginia, May 1982.

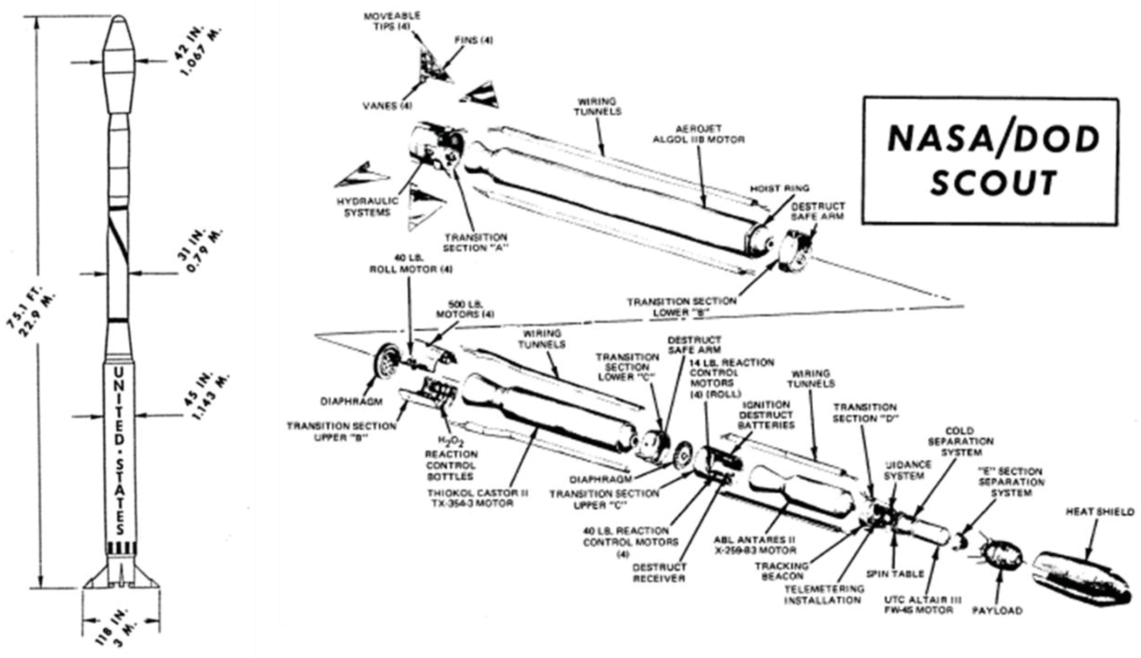


Figure 1. Scout D1 Configuration

The Scout program operated from three ground launch sites (Figure 2):

- Wallops Flight Facility (WFF), Virginia
- Vandenberg AFB, California
- San Marco, Kenya (offshore platform; effort managed by Europe/Italy)

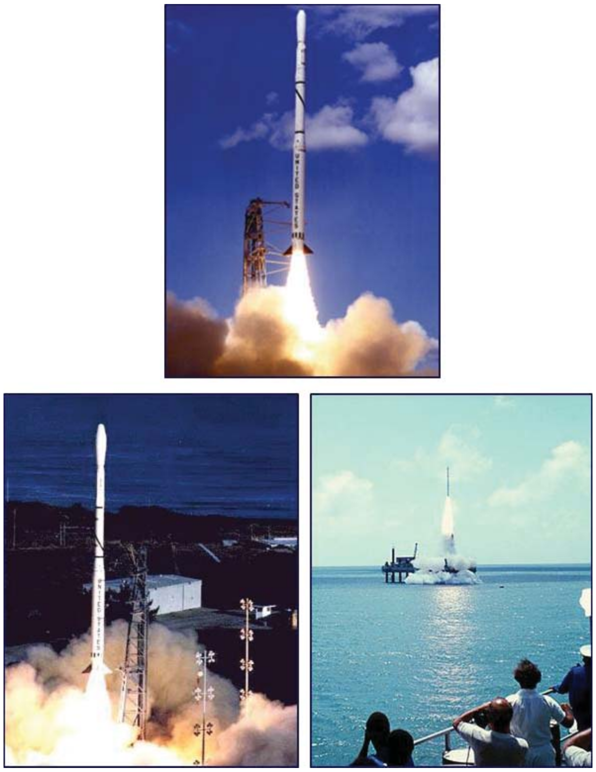


Figure 2. Scout Launch Sites

Wallops Flight Facility in Virginia (top), Space Launch Complex 5 (SLC-5) at Vandenburg AFB, California (left), and San Marco Island, off the east coast of Kenya

The average operational flight rate, accounting for a start-up test period, was estimated at 5.3 per year in the time frame of the NASA CR data (Table 1). The maximum achieved was around 10 per year. The actual launch capacity, had enough resources been available to the Scout Program, would appear to be at least 16 flights per year when summing the maximum achieved flight rate out of each of the three launch facilities (eight out of Wallops, plus six out of VAFB, plus two out of Africa). However, because the production line capacities were not documented, this could not be verified. Thus, it was assumed that a combination of budget and flight opportunities constrained the utilization rate of the Scout infrastructure.

Table 1. Scout Launch Record for Period Without Available Cost Data (1960–79)

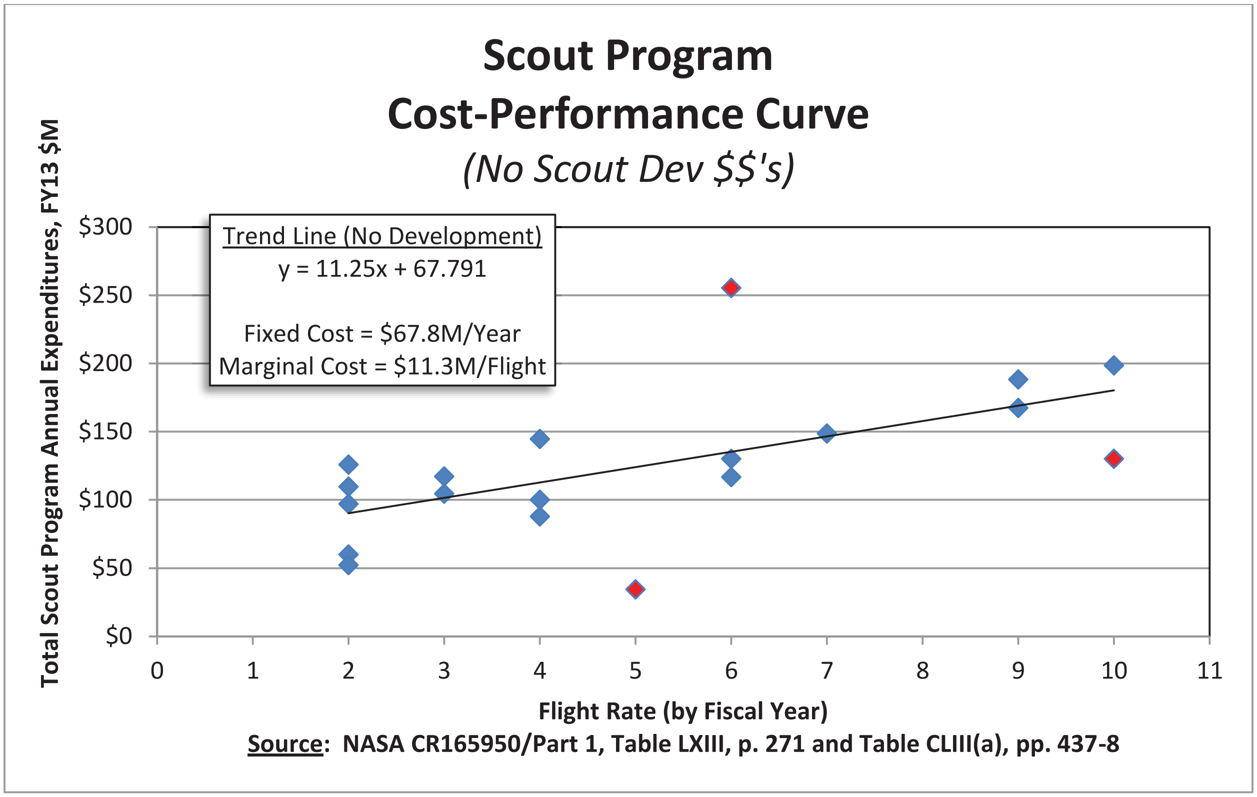
Calendar Year	Test Flights	Operational Flights	Total Flights (n)	Failed Flights	Successful Flights (k)	WFF Flights	WTR Flights	San Marco, Kenya, Africa Flights
1960	3	0	3	1	2	3	0	0
1961	4	0	4	2	2	3	0	0
1962	8	0	8	3	5	4	4	0
1963	8	1	9	4	5	3	6	0
1964	0	11	11	1	10	6	5	0
1965	0	5	5	0	5	3	2	0
1966	0	9	9	0	9	2	7	0
1967	0	9	9	2	7	1	7	1
1968	0	7	7	0	7	3	4	0
1969	0	2	2	0	2	0	2	0
1970	0	4	4	0	4	2	1	1
1971	0	7	7	0	7	4	1	2
1972	0	5	5	0	5	1	3	1
1973	0	1	1	0	1	0	1	0
1974	0	6	6	0	6	0	4	2
1975	0	3	3	1	2	0	2	1
1976	0	3	3	0	3	1	2	0
1977	0	1	1	0	1	0	1	0
1978	0	1	1	0	1	0	1	0
1979	0	3	3	0	3	2	1	0

Next, the budgeted costs for the same years in the Scout Program yielded the data in Table 2. Years that were dominated by nonrecurring costs were noted in red (i.e., 1961, 1962, 1966), as the team's focus was on recurring cost analysis.

Table 2. Scout Program Budgeted Cost History

Year	Flights Delivered	Budget (FY13 $M)	Budget Factors (NASA 2012 Inflation Index)	Then-Year Budget ($M)	Then-Year Budget, No Development ($M)
1961	5	$34	11.456	$19.754	$3.000
1962	6	$255	11.016	$26.088	$23.178
1963	10	$199	10.643	$22.148	$18.664
1964	6	$130	10.185	$12.762	$12.762
1965	9	$167	9.850	$16.996	$16.996
1966	10	$130	9.292	$13.980	$13.980
1967	9	$188	8.858	$21.253	$21.253
1968	7	$149	8.405	$17.693	$17.693
1969	3	$104	7.951	$13.133	$13.133
1970	2	$126	7.438	$16.924	$16.924
1971	6	$117	6.997	$16.665	$16.665
1972	2	$110	6.620	$16.553	$16.553
1973	3	$117	6.263	$18.704	$18.704
1974	4	$145	5.842	$24.768	$24.768
1975	4	$88	5.273	$16.655	$16.655
1976	4	$100	4.837	$20.701	$20.701
1977	2	$60	4.367	$13.707	$13.707
1978	2	$97	4.051	$23.962	$23.962
1979	2	$52	3.699	$14.108	$14.108

Combining information from Table 2 (cost per year) and Table 1 (flights per year), a cost-performance curve for the architecture was drawn.



Source: NASA CR165950/Part 1, Table LXIII, p. 271 and Table CLIII(a), pp. 437-8

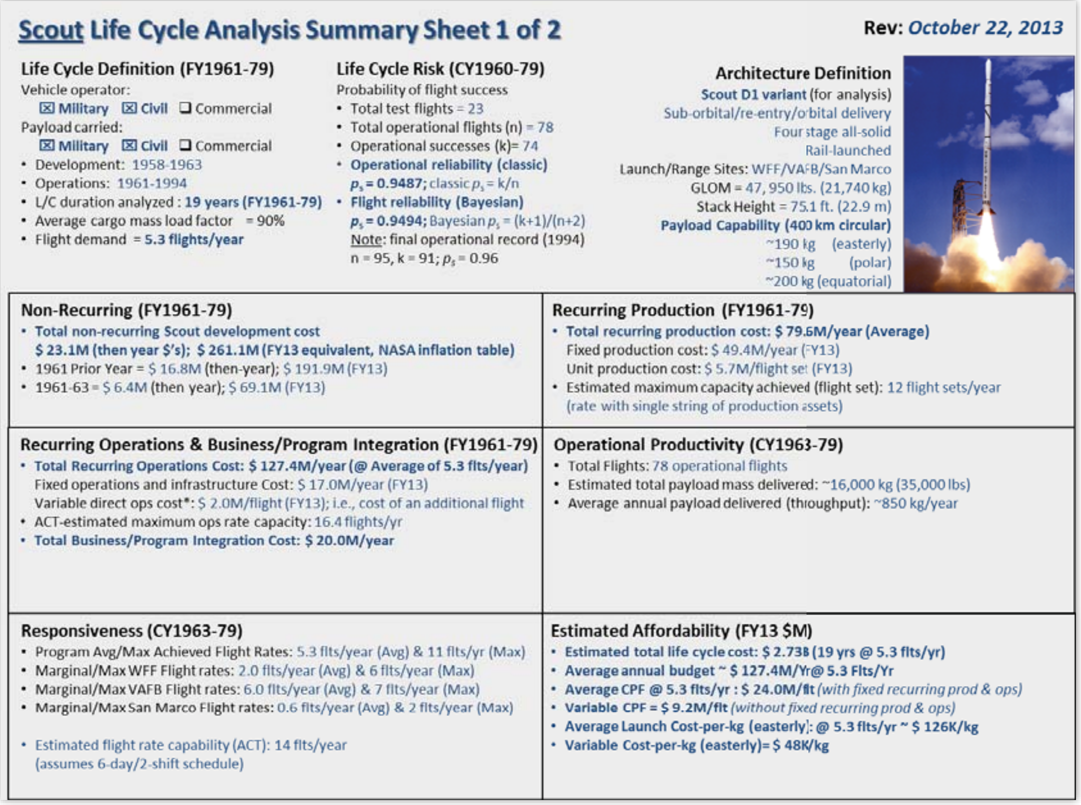
Figure 3. Derived Cost-Performance Curve for Scout Program

From the curve in Figure 3, a rough-order unit cost and fixed cost could be estimated. These values would act as the costing anchor point for a four-stage all-solid small launcher with business-as-usual government-contracted production and operations.

The next task was to capture the design characteristics of the Scout launch vehicle—element by element, subsystem by subsystem—and the major technology components and assemblies. This was accomplished by recreating a system design definition in the ACT's prototype architectural definition tool (Appendix A).

Engineering assessments quantified an index value for the functional interfacing/interconnecting complexity (onboard and offboard), along with other overhead index values for such characteristics as toxicity, ordnance, and confined space. The tool also requires an engineering assessment assignment of an index value for relative reusability. This was a trivial assessment for the concepts under review, since they are expendable.

With this type of information in hand, the prototype affordability assessment tool was run and ultimately provided the data profile for the Scout anchor case, which was compiled and summarized in Figure 4.



Scout Life Cycle Analysis Summary Sheet 1 of 2

Rev: *October 22, 2013*

Life Cycle Definition (FY1961-79)

Vehicle operator:

☒ **Military** ☒ **Civil** ☐ Commercial

Payload carried:

☒ **Military** ☒ **Civil** ☐ Commercial

- Development: 1958-1963
- Operations: 1961-1994
- L/C duration analyzed : **19 years (FY1961-79)**
- Average cargo mass load factor = 90%
- Flight demand = **5.3 flights/year**

Life Cycle Risk (CY1960-79)

Probability of flight success

- Total test flights = 23
- Total operational flights (n) = 78
- Operational successes (k)= 74
- **Operational reliability (classic)**
  p_s = 0.9487; classic p_s = k/n
- **Flight reliability (Bayesian)**
  p_s = 0.9494; Bayesian p_s = (k+1)/(n+2)
  Note: final operational record (1994)
  n = 95, k = 91; p_s = 0.96

Architecture Definition

Scout D1 variant (for analysis)
Sub-orbital/re-entry/orbital delivery
Four stage all-solid
Rail-launched
Launch/Range Sites: WFF/VAFB/San Marco
GLOM = 47, 950 lbs. (21,740 kg)
Stack Height = 75.1 ft. (22.9 m)
Payload Capability (400 km circular)
~190 kg (easterly)
~150 kg (polar)
~200 kg (equatorial)

Non-Recurring (FY1961-79)

- **Total non-recurring Scout development cost**
  $ 23.1M (then year $'s); $ 261.1M (FY13 equivalent, NASA inflation table)
- 1961 Prior Year = $ 16.8M (then-year); $ 191.9M (FY13)
- 1961-63 = $ 6.4M (then year); $ 69.1M (FY13)

Recurring Production (FY1961-79)

- **Total recurring production cost: $ 79.6M/year (Average)**
  Fixed production cost: $ 49.4M/year (FY13)
  Unit production cost: $ 5.7M/flight set (FY13)
- Estimated maximum capacity achieved (flight set): 12 flight sets/year
  (rate with single string of production assets)

Recurring Operations & Business/Program Integration (FY1961-79)

- **Total Recurring Operations Cost: $ 127.4M/year (@ Average of 5.3 flts/year)**
  Fixed operations and infrastructure Cost: $ 17.0M/year (FY13)
  Variable direct ops cost*: $ 2.0M/flight (FY13); i.e., cost of an additional flight
- ACT-estimated maximum ops rate capacity: 16.4 flights/yr
- **Total Business/Program Integration Cost: $ 20.0M/year**

Operational Productivity (CY1963-79)

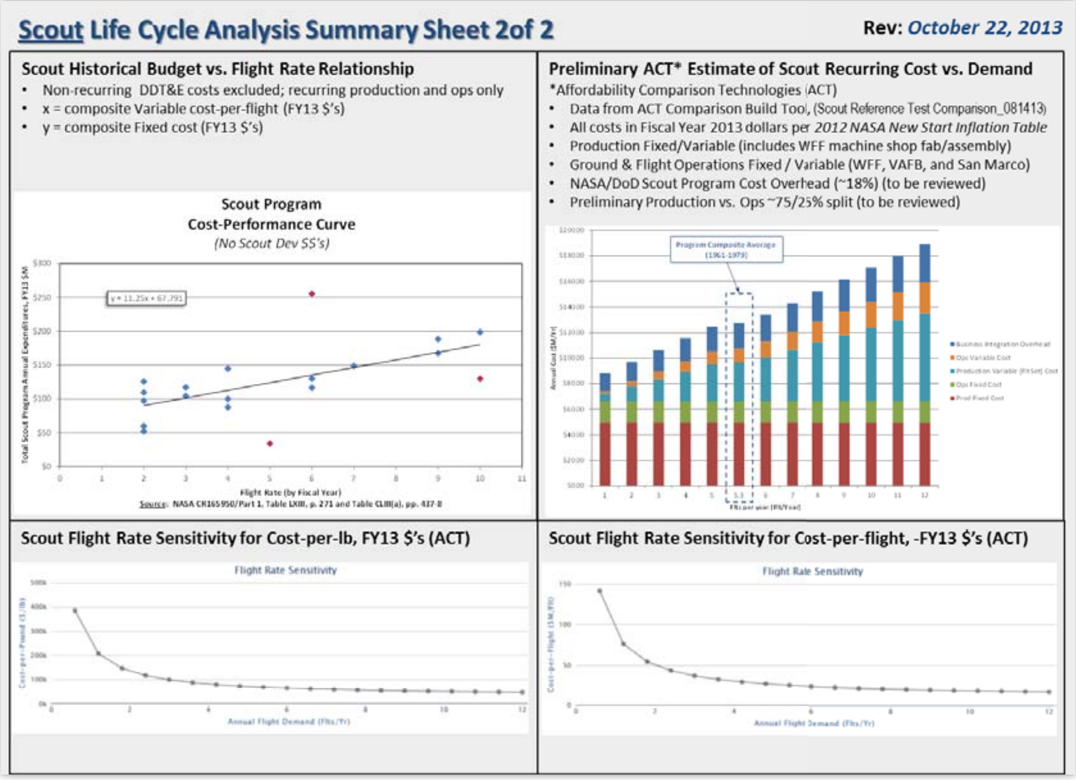
- Total Flights: 78 operational flights
- Estimated total payload mass delivered: ~16,000 kg (35,000 lbs)
- Average annual payload delivered (throughput): ~850 kg/year

Responsiveness (CY1963-79)

- Program Avg/Max Achieved Flight Rates: 5.3 flts/year (Avg) & 11 flts/yr (Max)
- Marginal/Max WFF Flight rates: 2.0 flts/year (Avg) & 6 flts/year (Max)
- Marginal/Max VAFB Flight rates: 6.0 flts/year (Avg) & 7 flts/year (Max)
- Marginal/Max San Marco Flight rates: 0.6 flts/year (Avg) & 2 flts/year (Max)
- Estimated flight rate capability (ACT): 14 flts/year
  (assumes 6-day/2-shift schedule)

Estimated Affordability (FY13 $M)

- **Estimated total life cycle cost: $ 2.73B (19 yrs @ 5.3 flts/yr)**
- **Average annual budget ~ $ 127.4M/Yr@ 5.3 Flts/Yr**
- **Average CPF @ 5.3 flts/yr : $ 24.0M/flt** *(with fixed recurring prod & ops)*
- **Variable CPF = $ 9.2M/flt** *(without fixed recurring prod & ops)*
- **Average Launch Cost-per-kg (easterly): @ 5.3 flts/yr ~ $ 126K/kg**
- **Variable Cost-per-kg (easterly)= $ 48K/kg**



Scout Life Cycle Analysis Summary Sheet 2of 2

Rev: *October 22, 2013*

Scout Historical Budget vs. Flight Rate Relationship

- Non-recurring DDT&E costs excluded; recurring production and ops only
- x = composite Variable cost-per-flight (FY13 $'s)
- y = composite Fixed cost (FY13 $'s)

Scout Program
Cost-Performance Curve
(No Scout Dev $$'s)

Source: NASA CR165950/Part 1, Table LXIII, p. 271 and Table CLIII(a), pp. 437-8

Preliminary ACT* Estimate of Scout Recurring Cost vs. Demand

*Affordability Comparison Technologies (ACT)

- Data from ACT Comparison Build Tool, (Scout Reference Test Comparison_081413)
- All costs in Fiscal Year 2013 dollars per *2012 NASA New Start Inflation Table*
- Production Fixed/Variable (includes WFF machine shop fab/assembly)
- Ground & Flight Operations Fixed / Variable (WFF, VAFB, and San Marco)
- NASA/DoD Scout Program Cost Overhead (~18%) (to be reviewed)
- Preliminary Production vs. Ops ~75/25% split (to be reviewed)

Scout Flight Rate Sensitivity for Cost-per-lb, FY13 $'s (ACT)

Scout Flight Rate Sensitivity for Cost-per-flight, -FY13 $'s (ACT)

Figure 4. Results of KSC Systems Integration Branch Anchoring Analysis and ACT Run for Scout

2.2.2 Concepts 1 and 2 – Nanolauncher System Concepts

The NASA Langley Vehicle Analysis Branch was tasked by the Game Changing Development Principal Investigator to derive a set of nanolauncher concepts (see Figure 5).

As small as the Scout payload capability was, dramatic reductions in launch vehicle size can be seen in Figure 5 by dropping the payload delivery requirement from less than 200 kg to only 5 kg. Specific conceptual design goals and requirements are shown in Figure 6. The question to be answered was whether the cost per launch would scale down similarly.

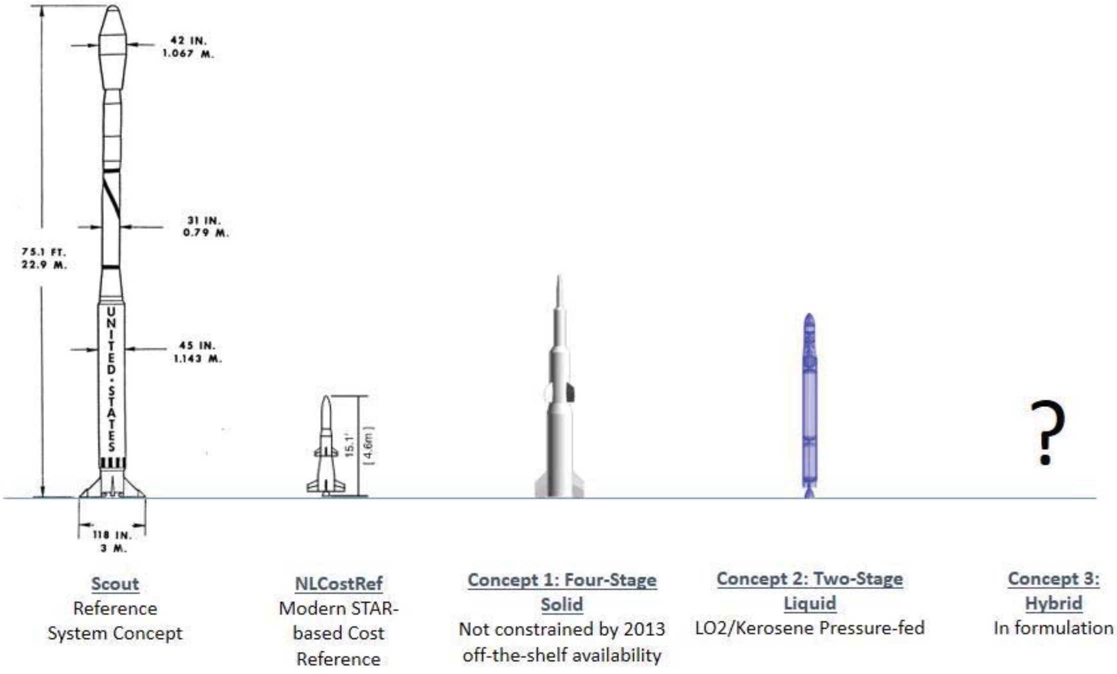
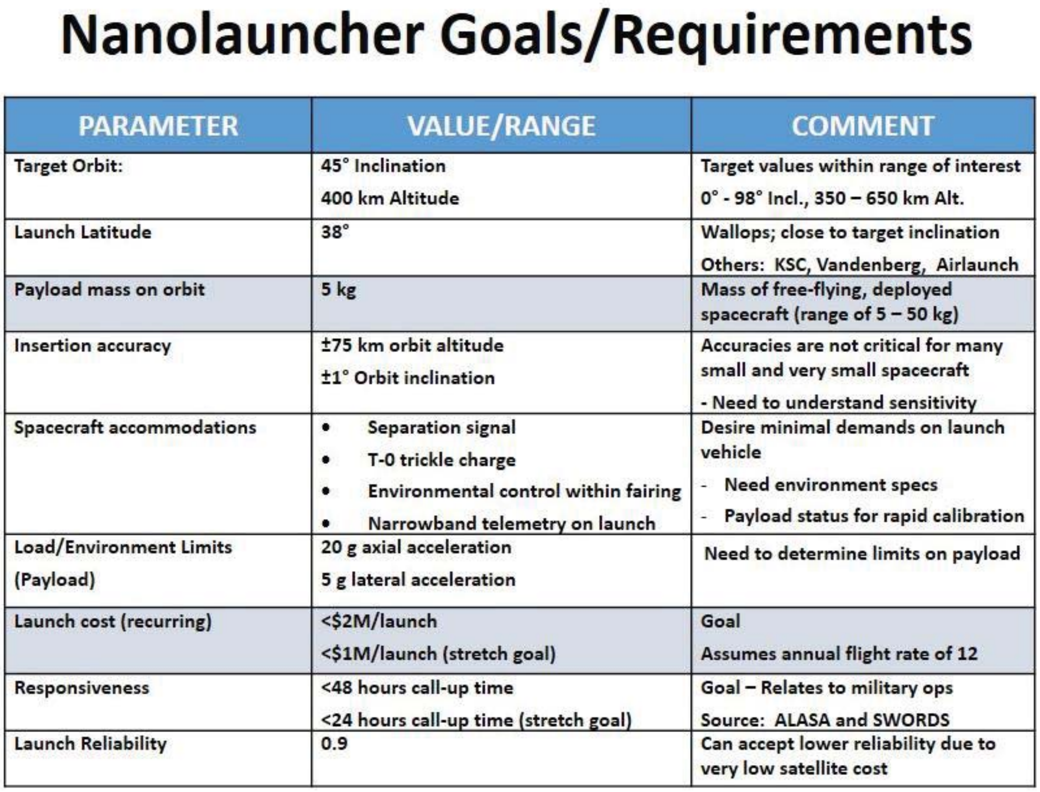


Figure 5. Comparative Scale of Concepts Considered for Comparison

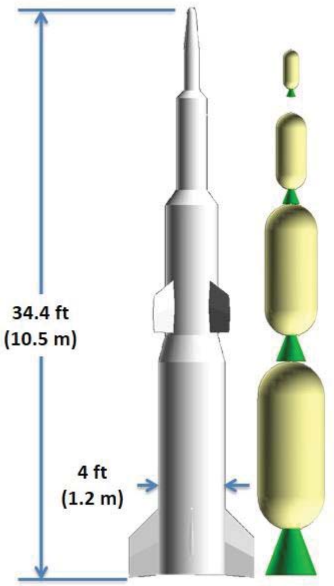


Nanolauncher Goals/Requirements

PARAMETER	VALUE/RANGE	COMMENT
Target Orbit:	45° Inclination 400 km Altitude	Target values within range of interest 0° - 98° Incl., 350 – 650 km Alt.
Launch Latitude	38°	Wallops; close to target inclination Others: KSC, Vandenberg, Airlaunch
Payload mass on orbit	5 kg	Mass of free-flying, deployed spacecraft (range of 5 – 50 kg)
Insertion accuracy	±75 km orbit altitude ±1° Orbit inclination	Accuracies are not critical for many small and very small spacecraft - Need to understand sensitivity
Spacecraft accommodations	• Separation signal • T-0 trickle charge • Environmental control within fairing • Narrowband telemetry on launch	Desire minimal demands on launch vehicle - Need environment specs - Payload status for rapid calibration
Load/Environment Limits (Payload)	20 g axial acceleration 5 g lateral acceleration	Need to determine limits on payload
Launch cost (recurring)	<$2M/launch <$1M/launch (stretch goal)	Goal Assumes annual flight rate of 12
Responsiveness	<48 hours call-up time <24 hours call-up time (stretch goal)	Goal – Relates to military ops Source: ALASA and SWORDS
Launch Reliability	0.9	Can accept lower reliability due to very low satellite cost

Figure 6. Nanolauncher Concept Assessment Goals and Requirements

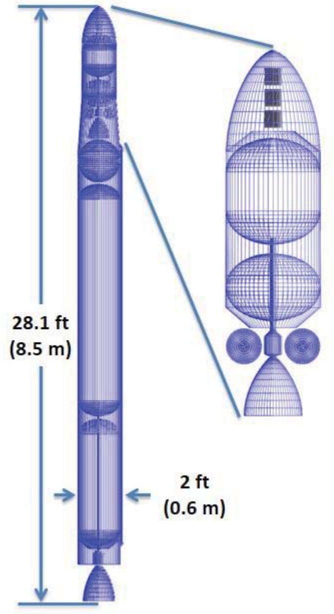
Several concept approaches were pursued by LaRC. One approach was to essentially reproduce a Scout, using today’s technology, at the size class required. This would involve designing a small, four-stage, all-solid configuration. This would be assembled and launched on an angled launch rail to avoid the need for flight termination ordnance on the first two stages. The first iteration of this design, used during the early phases of the study, is shown in Figure 7. An ACT architectural definition was constructed for NL001 and is provided in Appendix B.



- Baseline Design and Technology Assumptions
  - **Payload Mass:** 10 kg (5 kg target)
  - **Configuration:** 4-Stage, Expendable
  - **Launch Mode:** Rail launch
  - **Propulsion:** All solid
  - **Propellants:** HTPB
  - **Structures:** All composite
  - **Guidance & Cntrl:** Spin/Fin stabilized + ACS
  - **FTS:** Destruct (stages 3 & 4 only)
  - **Vehicle Integration:** Horizontal
  - **Acquisition Concept:** Traditional/Gov.
  - **Manufacturing/Ops/Launch Approach:** Traditional/Business-As-Usual
- Performance Characteristics
  - **Dry Mass:** 630 kg
  - **Gross Mass:** 8130 kg

Figure 7. Concept 1, NL001, Four-Stage All-Solid Nanolauncher

The second approach was a two-stage all-liquid, LO_2/kerosene nanolauncher (see Figure 8). From the standpoint of complexity, this concept would have fewer elements, but would have more active systems (pumps, valves, sensors, ground loading equipment, and so forth). It was not clear how the stack-up of infrastructure and operations would trade across the life cycle. An ACT architectural definition was constructed for NL002 and is provided in Appendix C.



- Baseline Design and Technology Assumptions
  - **Payload Mass:** 9 kg (5 kg target)
  - **Configuration:** 2-Stage, Expendable
  - **Launch Mode:** Pad launch
  - **Propulsion:** Pressure-fed – He w/HX
  - **Propellants:** LOX, RP-1 (mix ratio 2.6)
  - **Structures:** All composite
  - **Guidance & Cntrl:** TVC – Battery/EMA
  - **FTS:** Thrust cutoff + Destruct
  - **Vehicle Integration:** Horizontal
  - **Acquisition Concept:** Traditional/Gov.
  - **Manufacturing/Ops/Launch Approach:** Traditional/Business-As-Usual
- Performance Characteristics
  - **Dry Mass:** 255 kg
  - **Gross Mass:** 1800 kg

Figure 8. Concept 2, NL002, Two-Stage All-Liquid Nanolauncher

2.2.2.1 Comparison Ground Rules and Assumptions

The flight vehicles for comparison needed a common set of ground rules and assumptions for comparing recurring production, ground, and flight operations. Also, a number of business practice assumptions had to be made in comparing historical NASA-run launch architecture with entrepreneurial methods and practices in the commercial space launch arena, for example.

Two types of inputs are required:

- those relating to the system definition
- those relating to the business process scenarios

The comparisons can look across both the nonrecurring and the recurring segments of the life cycle. Since the focus was not on acquisition of a nanolauncher system, but rather on the long-term benefits of technology investments (and because of the time and resources available), the effort focused on the recurring segment of the life cycle. Of particular interest was whether the recurring launch costs could be less than \$1M–\$2M per flight. With that in mind, the ACT prototype can provide insight into the following information:

- Recurring production/logistics supply chain
    - Annual fixed costs (labor, materials, and other charges)
    - Unit costs (labor, materials, and other charges)
    - Production rate (per line of production capability)
- Recurring operations (at the launch site and for flight operations)
    - Annual fixed costs (labor, materials, and other charges)
    - Direct flight costs (labor, materials, and other charges)
    - Flight rate capability (per line of production capability)
- Recurring business, or program, integration (for functions that administer the enterprise across production and operations). This allows for comparing:
    - parameters related to administrative overhead efficiency (those that are cross-functional to production and operations tasks, such as customer marketing, business and legal tasks, payroll and taxes, etc.)
    - parameters that compare and relate the efficiency of production and operation fixed labor levels
    - parameters that compare and relate the levels of direct work per task and responsiveness of the operation
    - average utilization rates (as compared to sustained and surge rate capabilities). This allows comparisons of system demand rates on the architecture.

2.2.3 System Design Contributors to Life Cycle Drivers

The comparisons discriminate key design characteristics, and derive life cycle values from a series of parametric values formed from inputs made by the KSC Systems Integration analyst from the anchor data (in this case, the Scout D1 launcher). Many design characteristics add cost and complexity. However, the following have been found to have extensive life cycle implications, and not just ground operations impact.[2,3] Some of the key design drivers included in the prototype comparison tool are the following.

- *Total number of elements* to design, fabricate, test, transport, assemble, check out, service, and operate. The more elements, the greater the accumulated costs.
- *Total number of subsystems, components, assemblies* to design, acquire, set up a supply chain, install, check out, service, repair (as needed), and operate.
- *Total number of functional interfaces/interconnections:* whether the design item is required to be powered, loaded, pressurized, calibrate, filtered, etc.
- *Subsystems with toxic commodities specified:* These create added infrastructure requirements and lower system productivity as a result of personnel required to operate in restrictive personnel protective equipment—such as self-contained atmospheric protection ensemble (SCAPE) suits, and the infrastructure cost of owning such suits, or the added service cost and time in using a suit service. Specifying such systems adds work (cost and time) to the design process, fabrication, and testing. For the nanolauncher concepts, no toxic commodities were specified.
- *Subsystems with ordnance/pyrotechnics specified:* Depending on the variety, these may require special facilities to contain the explosive hazard, such as blow-out panels, bunkers, and special design functions such as spark-arresting and suppression and static discharge control. This is a particularly noteworthy characteristic to consider in the NL001 concept. In addition, these systems cause stop-work periods and require safety clearance zones to be established. Methods of staging vehicles often employ ordnance and pyrotechnic design methods.
- *Vehicle configuration with many confined spaces:* Depending on the size or location with certain fluid and gas commodities, or both, these compartments may require safety purges, which in turn may require added subsystems. In addition, if large enough, these areas are popular locations for collecting subsystem components, and therefore, the designer may assume that internal personnel access is required for routine servicing operations. For the nanolaunchers, these were not a major concern in the concepts. However, these areas are often overlooked in mass estimates and sizing during the early concept phase. These

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[2] Zapata, E., *et al.*, *Design Guide for Highly Reusable Space Transportation*, Space Propulsion Synergy Team, NASA Kennedy Space Center, Florida, August, 1997.

[3] NASA TM-2005-214062, *NASA's Exploration Systems Architecture Study*: *Final Report*; NASA Headquarters, Washington, D.C., November, 2005.

"transition pieces" accumulate subsystem functions that cannot be installed elsewhere. In concept drawings, these transition spaces may not reveal to the untrained eye the internal nature or complexity of functions occurring inside them. In short, the accumulation of elements, main storage vessels, subsystems, components, and assemblies as a result of confined spaces causes excess design, fabrication, acquisition, testing, operations, and equipment support.

- *Reusability:* The degree of reuse of a subsystem component or assembly can also be a factor, depending on the concept. If an end item is recovered, the degree to which functional integrity is retained by the element, the subsystems, and their components has a great influence on the degree of work and infrastructure needed to support each flight. However, for the ALTIA nanolauncher activity, all concepts were completely expendable. In the ACT prototype, this meant setting the Reusability Index (RI) to zero. The RI factor is a scale of −1.0 to +2.0, where: zero represents an expended item; 2.0 represents the degree of reusability and functional retention upon return of a commercial airliner; and −1.0 represents a recovered item that has infrastructure to retrieve and return the element, disassemble and clean the element, reassemble and/or remanufacture the subsystems into the element, and deliver the remanufactured element to the ground operator.

Note that other design drivers have been considered, such as cryogenics and high-pressure systems. However, the drivers described above have been found to have a sweeping cumulative effect on work across the life cycle and/or creation of unique infrastructure (facilities and special equipment). Often a system driver may be the added auxiliary subsystems and end items, such as cryogenics. In these cases, the System Count Index feature in the System Breakdown Structure tool will reveal this complexity.

For the small nanolaunchers and the Scout vehicle reviewed, the toxic commodity and confined spaces indices were addressed. However, they were rarely found to be an influencing factor—if at all.

2.2.4 Business Processes and Practices as Life Cycle Drivers

Having defined the launch vehicle, it was necessary for the team to define assumptions for the workforce, using the envisioned architecture, since labor costs tend to dominate launch costs.

This allowed *apples-to-apples* comparisons while exploring technical changes to the architecture, and also allowed the technical characteristics to be held constant while exploring the projected impact of differently assumed business processes and practices.

Therefore, a set of *business case scenarios* was developed independent of the system definition for input into ACT. These were embodied in the study in several business scenarios with reduction factors based on the BAU settings:

a. *100% = BAU* – Business as usual (e.g., a traditionally contracted sounding rocket)

b. *70% = COTS* – Commercial off-the-shelf (COTS) purchases

c. *40% = COM* – Commercial best practices—entrepreneurial business in the competitive commercial marketplace

The BAU assumptions were modeled on the Scout anchor point. That is, the BAU scenario assumed a government/contract cost-plus type of contract arrangement to routinely produce and fly the vehicle.

The following input parameters are adjusted as inputs to the comparison for these two different business cases:

- Flight systems design skill level (i.e., labor rates assumed for design)
- Production and ground systems design skill level/experience (i.e., labor rates assumed for design)
- Operations process efficiency/burden (i.e., average number of people who are paid to conduct and observe a task)
- Production and operations skill level/experience (i.e., labor rates assumed for nanolauncher [NL] fabrication and operation)
- Business integration overhead factors (e.g., administrative support, information management and IT, human resources support, payroll, management, legal counsel, marketing)

Changes in assumptions about these parameters affect the internal algorithms in the ACT tool, which performs an on-the-fly parametric analysis based on the anchor data provided. In comparing the proposed vehicles, these types of parameters are normally ground-ruled and assumed to be the same.

For this analysis, however, it was not clear to what extent these business assumptions might impact the life cycle cost and productivity outcome, versus simply a technical change in design only. Perhaps only design changes were needed, or both design and business process changes might be needed. Or perhaps changes in both would not be enough to get to the target affordability value of $1M–$2M per flight.

2.3 Comparison 1 Results

2.3.1 Summary of Comparison 1 Results

Result 1 – Production and fabrication costs drive the recurring costs of expendable nanolaunchers by a factor of 3 over ground and flight operations costs. (Partially reusable nanolauncher architectures have not yet been analyzed.)

Result 2 – Total annual recurring costs are dominated by the fixed costs at flight rates lower than one per month. Flight rate variable costs are steep, owing to the expendability of all flight hardware in the concepts under analysis.

Result 3 – For the areas driving work and the materials cost (i.e., production costs, fixed costs, and low flight rate), the stack-up of separate flight elements is an important design driver, as well as the total number of subsystems required to be separately designed, tested, produced/procured, supported, and operated.

Result 4 – Neither of the concepts (all-solid or all-liquid), by themselves with off-the-shelf technologies and business as usual integration approaches, achieved the low costs needed—even at high utilization rates. A combination of high system utilization and use of commercial best practices appears to come close to, but does not quite achieve, the cost-per-flight objective. Modest technology investments might, however, achieve the affordability and responsiveness needed by the nano space community.

2.3.2 Result 1 Discussion

The major recurring cost elements for the Scout anchor case are shown in Figure 9. The largest contributor was the recurring production and fabrication costs. In addition, the fixed support costs of the Scout Program dominated the recurring costs.

The production and fabrication element includes the costs for procuring and making the various Scout motor stages, the stage transition pieces, the electrical components, etc.

The ground and flight operations costs were those accumulated at the launch point for preparing and conducting Scout spaceflights at the three launch complexes across the world. As a result of the distributed operations and infrastructure, ACT was also provided the number of *strings* of infrastructure in the business case scenario; in this case, there was three (WFF, VAFB, and San Marco). This allowed the tool to report comparisons on a single launch site basis, or for a single string of production and operations assets. This also verified that, given the various Scout vehicle and business scenario assumptions, the ACT model outputs matched the anchor values researched.

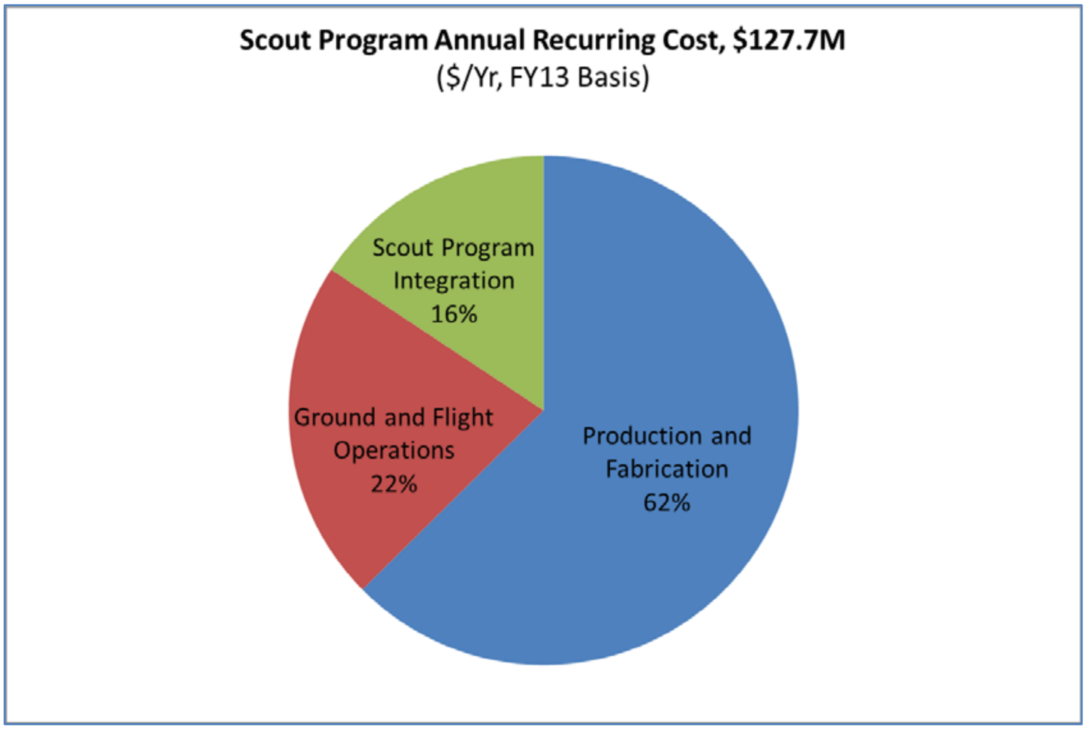


Figure 9. Scout Production and Operations Recurring Cost (at 5.3 flights per year)

2.3.3 Result 2 Discussion

The recurring costs were also checked in ACT for the split between fixed versus flight rate variable cost components. The ACT output for the total annual fixed and variable costs is shown in Figure 10. The fixed costs are costs required to support the program capability, regardless of how many flights were produced. These are costs paid per year, rather than per unit (for variable production costs), or per launch (for variable ground and flight operations costs). The comparison runs assumed an approximate 20-year program average. A stack-up of these cost components as a function of flight rate (as determined by ACT) is provided in Figure 11. The figure is a modeled reproduction of the cost performance curve researched and shown previously in Figure 3.

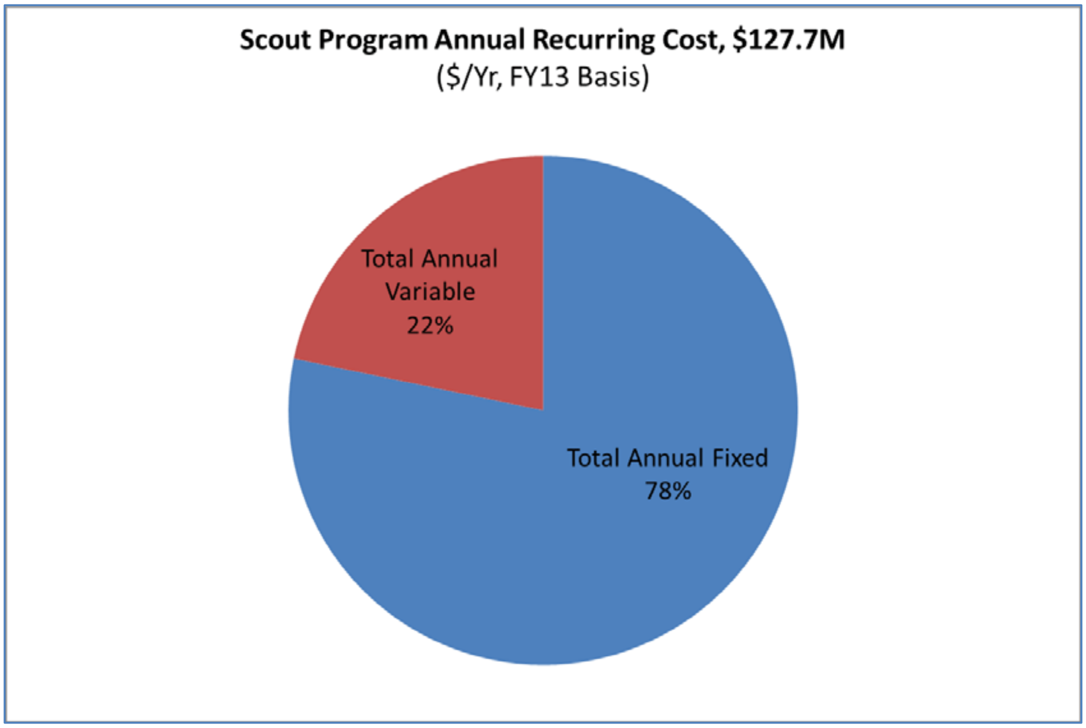


Figure 10. Scout Anchor Values for Annual Fixed and Variable Cost in Today's Dollars

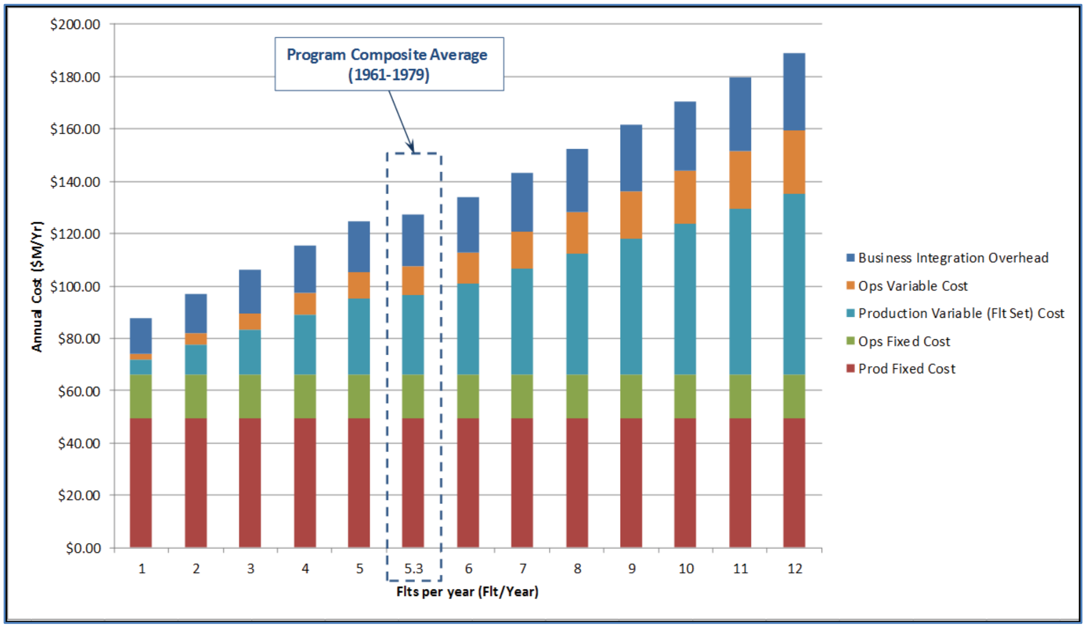


Figure 11. Scout Cost-Performance Curve with Contributing Cost Components (ACT-modeled)

2.3.4 Result 3 Discussion

Having identified the recurring life cycle cost behavior, the next task was to explore system design and business practice influences on these life cycle cost elements and to compare the Scout historical launch vehicle against the concept vehicles with those influences modeled—at least in a relative sense.

The number of different components, and components with overhead factors related to them (engineering judgment for each line item of the system definition, with descriptions), are compared in Table 3. The values shown were derived from the Functional System Breakdown Structure Tool, described in Section 4, and the life cycle drivers described in Section 2.2.3.

Table 3. Summary Comparison of Concept SBS Complexity Indices (Comparison 1)

Vehicle	System Count Index	Total Interface/Interconnections Complexity Index	Normal Interface/Interconnections Complexity Index	Toxic Interface/Interconnections Overhead Index	Ordnance Interface/Interconnections Overhead Index	Confined Spaces Interface/Interconnect. Overhead Index
Scout D1 – Four Stage/All-Solid	106	397	334	0	63	0
NL001 – Four-Stage/All-Solid	111	344	302	0	42	0
NL002 – Two-Stage/LO2-kerosene	123	370	257	0	26	87

The values are accumulated for each of the line items in the concept system definition sheets, which were assigned by the life cycle analyst (estimated masses were also assigned or allocated by the flight and performance analysts at LaRC/VAB). In the prototype ACT version used, this included:

- *System Count Index* – an index comparing rough-order-of-magnitude subsystem/component estimates.
- *Total Interface/Interconnections Complexity Index* – an index comparatively estimating the complexity of the flight-to-flight element and flight-to-ground interfacing; along with comparative estimates of internal functional interface complexity in terms of electric power connections, telecommunications, software, mechanical, as well as plumbing interconnection complexity and likely complexity of thermal interfaces.

- *Toxic Interface/Interconnections Complexity Index* – an index component of the Total Interface/Interconnections Complexity Index related to toxic commodities (see Section 2.2.3).

- *Ordnance Interface/Interconnections Complexity Index* – an index component of the Ordnance Interface/Interconnections Complexity Index related to ordnance/pyrotechnic devices (see Section 2.2.3).

- *Confined Space Interface/Interconnections Complexity Index* – an index component of the Confined Spaces Interface/Interconnections Complexity Index related to interstitial spaces that might cause creation of safety purge subsystems (see Section 2.2.3).

- *Normal Interface/Interconnections Complexity Index* – an index component of the Normal Spaces Interface/Interconnections Complexity Index related to all other subsystems.

A more detailed breakdown of the compared concepts by stage is presented in Table 4.

One example for using these indexes to compare concepts and technologies is provided in Table 5 as an example. Comparing the solid avionics in NL001 versus liquid avionics in NL002 should favor solids in terms of a simpler avionics function and, thus, lower system count. However, consider that the solid version had four stages to command, control, and monitor, while the two slightly more complex stages in the liquid version had more subsystem components and assemblies within each to scar the life cycle. In balance, the two approaches totaled similarly.

Table 4. SBS System Count Index Comparison by Flight Element (Comparison 1)

Vehicle	System Count Index	Total Interface/Interconnections Complexity Index	Normal Interface/Interconnections Complexity Index	Toxic Interface/Interconnections Overhead Index	Ordnance Interface/Interconnections Overhead Index	Confined Spaces Interface/Interconnect. Overhead Index
Scout Algol IIIA First Stage	21	68	53	0	15	0
NL001 Solid First Stage	19	54	42	0	12	0
NL002 LO2/RP First Stage	54	157	107	0	5	45
Scout Castor IIA Second Stage	24	97	82	0	15	0
NL001 Solid Second Stage	18	47	40	0	7	0
NL002 LO2/RP Second Stage + P/L Accommodations & Fairing	69	213	150	0	21	42
Scout Antares IIA Third Stage	43	184	165	0	19	0
NL001 Solid Third Stage	43	118	107	0	11	0
Scout Altair IIIA Fourth Stage + P/L Accommodations & Fairing	18	48	34	0	14	0
NL001 Solid Fourth Stage + P/L Accommodations & Fairing	31	111	113	0	12	0

Table 5. System Count Index Comparison by Subsystem Type (Comparison 1)

Vehicle	Structure	Propulsion	Mechanisms	Power	Avionics	Thermal & Environmental Control	Payload Accom-modation
Scout D1 (Anchor)	32	20	9	22	23	0	0
NL001 All-Solid	18	25	7	12	38	8	3
NL002 (LO2/RP)	14	63	5	13	20	4	4

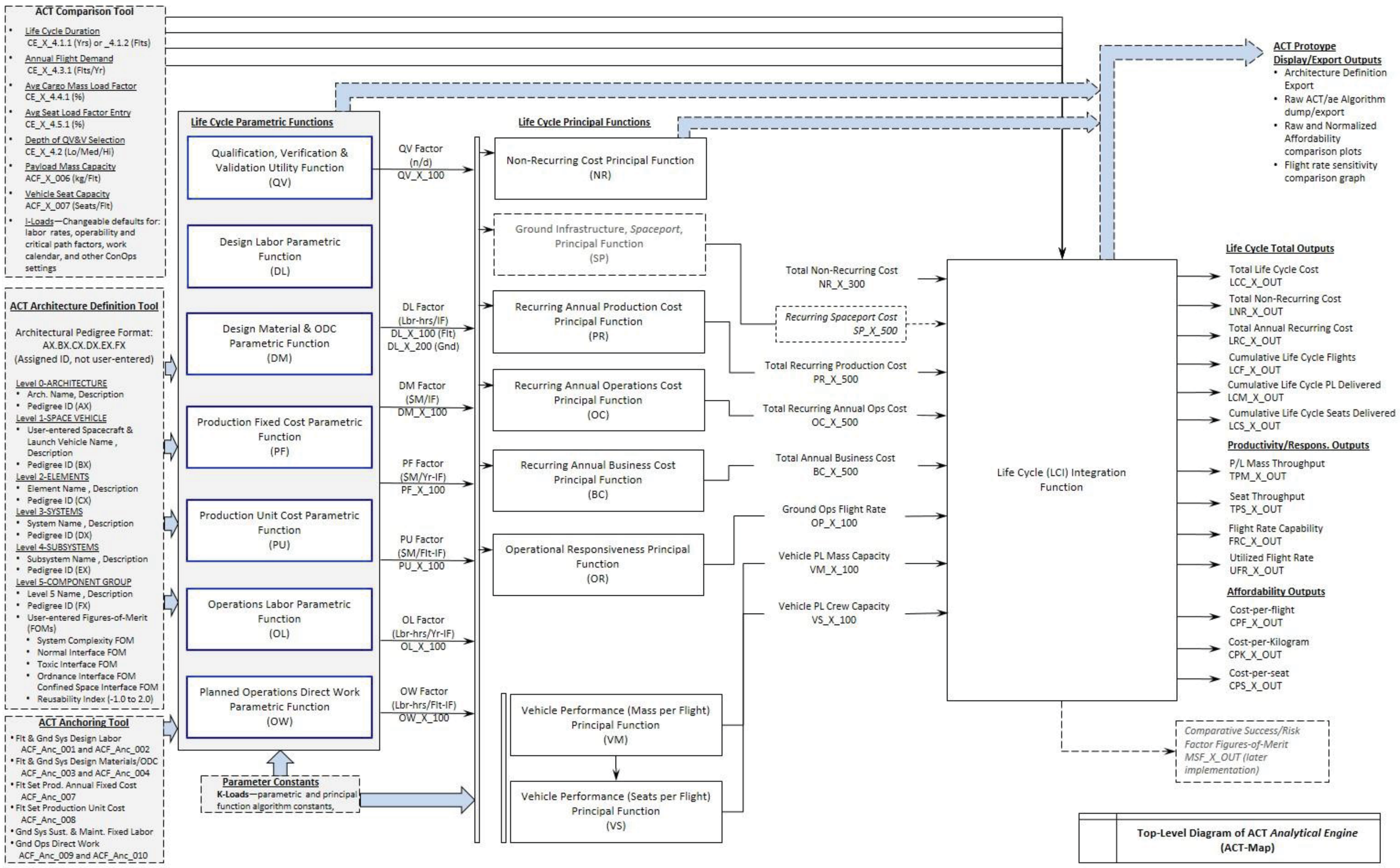


Figure 12. Affordability Comparison Tool (ACT) Algorithm Top-Level Functional Flow

2.3.5 Result 4 Discussion

In comparing the total recurring cost per flight, the results, as a function of flight rate—and assuming that business practices similar to those used in a NASA small launch vehicle or sounding rocket program—are shown in Figure 13. The figure compares the Scout reference with a cost reference provided by LaRC that assumed off-the-shelf prices and components from a STAR motor catalog (called the NL CostRef).

First, the figure shows that scaling down from a Scout-sized small-sat delivery capability to a nanosat-sized delivery capability, and upgrading from 1960s technology and design solutions to today’s, does indeed reduce cost.

Second, using the system at a higher flight rate—particularly beyond five or six flights per year—brings down the average cost per flight.

However, the main objective of creating nanolaunchers that are affordable enough to compete with alternatives, such as rideshares in larger launch vehicles, would need more than off-the-shelf material using business-as-usual (BAU) processes and practices.

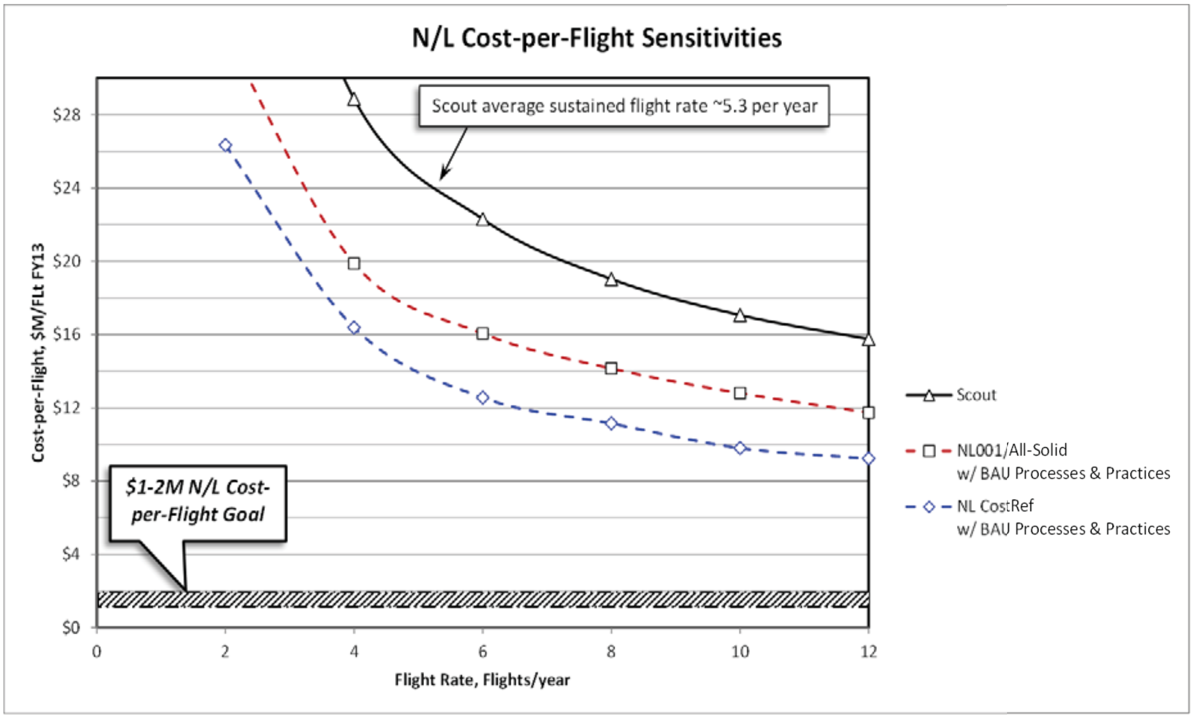


Figure 13. Cost-per-Flight Comparison with Business-as-Usual (BAU) Assumptions

In the next set of comparisons, the NL001/all-solid and NL002/all-liquid designs were compared to each other assuming BAU, and to each other assuming streamlined commercial practices.

The liquid and solid concepts showed similar cost advantages over, say, the Scout results, with the liquid having a slight advantage, primarily because of having fewer stages, and thus slightly fewer components.

One final check of the results in terms of life cycle analysis was to perform a sanity check on the business parameters. For example, if certain assumptions are made, does the resulting required level of labor level look reasonable? If it turns out that no more than, say, only a few individuals could be paid to run the entire production, ground operations, and business integration, then perhaps the whole business assumption for dedicated launchers of nanosats would be extremely difficult to achieve using any set of strategies. On the other hand, if reasonable assumptions allowed a reasonably sized workforce, then proceeding with a second phase of analysis would be warranted. With this in mind, a sanity check was run, assuming the following:

a. 15 launches per year
b. $1M launch price
c. Low fixed costs
d. Material costs contributing 25% of total annual costs (fixed and variable)
e. Labor contributing 75% of total annual costs (fixed and variable)

The result (and many variations could occur) yielded a recurring production, ground, and flight operation and a business integration team of about 120 individuals, when assuming an average labor rate of $75,000 per year. This is a low labor rate assumption, but leaves room to increase the labor rate and still have a reasonably large enough workforce to operate a well-managed nanolauncher enterprise.

The sanity check cleared the Comparison 1 results, and the notion that nanolauncher enterprises may be reasonable to pursue—particularly if a set of actionable improvement strategies were pursued.

2.4 Improvement Strategies

The results of Comparison 1 revealed that new strategies beyond using off-the-shelf components and changes in businesses practices would achieve launch costs competitive with alternatives to dedicated nanolaunchers.

2.4.1 Improvement Strategy 1 – System Design Improvement

The first strategy explored alternatives such as air-launched and towed glider concepts. However, these concepts could not be analyzed with the available time and resources.

2.4.2 Improvement Strategy 2 – Technology Integration

Rather than having a NASA internal system design effort pursue these alternative designs, the team focused on how technology advances emerging in NASA labs, industry labs, and commercial businesses could affect the life cycle outcome of the concepts at hand.

2.4.3 Improvement Strategy 3 – Business Processes and Practices Changes

In pursuing the third strategy of adjusting business practices and assumptions, the comparison tool adjusted factors related to these, as discussed in 2.2.4. The result was dramatically reduced fixed-cost components (Figure 14). However, the streamlined workforce would still have to contend, one way or another, with the complexities of either a many-stage solid configuration, or a more complex two-stage configuration, both assuming available technologies that have demonstrated themselves in actual spaceflight.

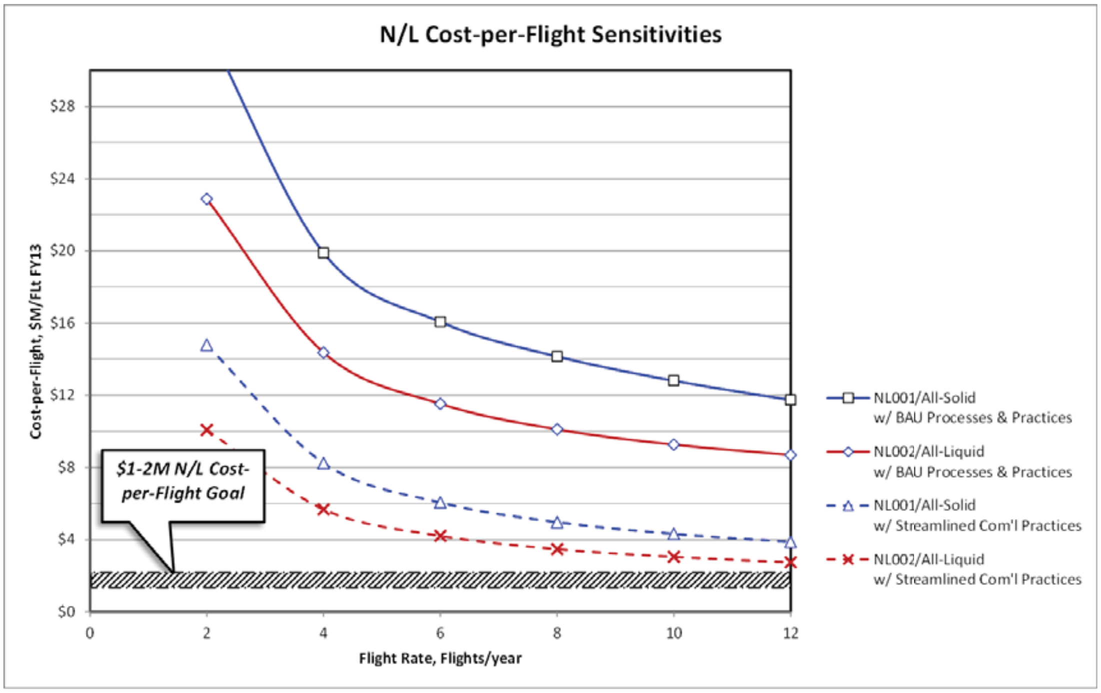


Figure 14. Comparing Nanolaunchers Under Two Different Business Assumptions

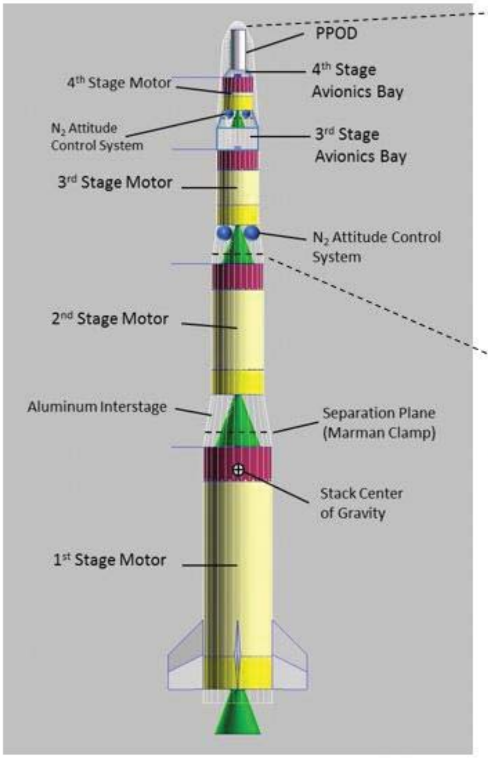
2.5 Comparison 2: Quantify Impact of Avionics Technologies on Nanolaunchers

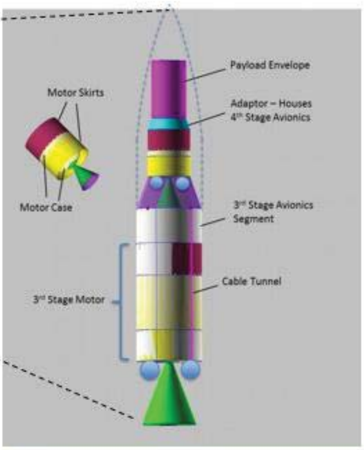
In the second phase of the ALTIA/Nanolauncher Study, the approach was to pursue three strategies in the following fashion:

a. Focus on one of the two nanolauncher configurations under study by the Langley team. The team chose the NL001/four-stage all-solid concept (Figure 7) as the context for technology analysis, was updated for Comparison 2 (Figure 15), and scaled-up in several versions for determining sizing sensitivities (Figure 16).

b. Pursue a specific set of technologies that might be examined for life cycle impact on the chosen configuration, but that could be applied to other nanolaunchers and other launch vehicles, as well as to the nanosats themselves. Advanced avionics technologies were chosen as the innovation area of interest for Phase II.

c. Also desired was some recommendation related to what was learned in the life cycle analysis and changes in government/industry roles in business processes and practices.





4th Stage Avionics

- IMU
- Flight Computer
- Attitude Control Driver Unit
- Power Management Unit
- Battery

3rd Stage Avionics

- IMU
- Attitude Control Driver Unit
- Telemetry Encoder Unit
- Telemetry Transmitter Unit
- Radar Transponder Unit
- Power Management Unit
- Batteries
- Flight Termination Units 1 and 2
- Flight Termination Batteries 1 and 2
- Flight Termination Pyro
- Telemetry, Radar & FTS Antennas
- Ground Interface Panel

MISSION & DESIGN

- Wallops rail launch, 45 deg inclination, 450 km orbit
- 4 Stage, solid motor (HTPB propellant)
- Titanium motor cases
- Aluminum inter-stages, adaptors, skirts, fins & shroud
- Spin stabilized during 1st and 2nd stage burns
- Cold gas (N2) attitude control systems on 3rd and 4th stages
- FTS and main avionics in 3rd stage forward bay
- Baseline assumes existing/SOA technology

Figure 15. Refined Four-Stage All-Solid NL001 System Configuration for Life Cycle Comparison 2

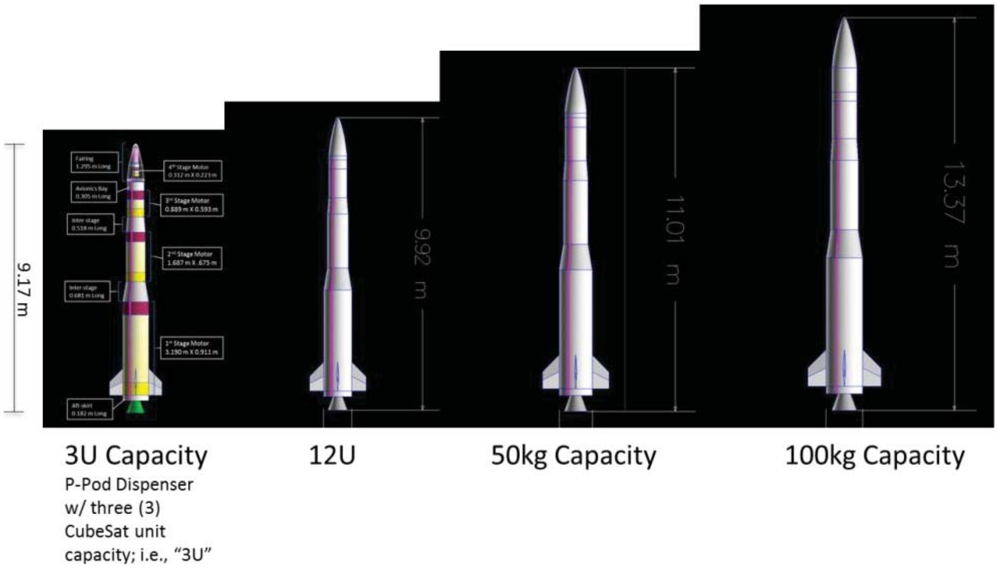


Figure 16. Nanolauncher Capacity Variants

2.5.1 Defining an Advanced Integrated Avionics Version of NL001 for Life Cycle Analysis

The NASA ALTIA team conducted numerous interviews, conference side talks, and telecom briefings with those engaged in creating and delivering miniaturized satellites and launchers, as well as interviews with engineering managers with RocketU at KSC and at NASA's Wallops Flight Facility (WFF).

In our initial comparisons, we looked for technologies that would integrate more functionality into fewer components and assemblies. We also looked at technologies with the potential to eliminate the need for entire flight subsystems, ground subsystems, and associated operations and infrastructure.

One area of interest was taking advantage of Advanced Flight Safety System (AFSS) technologies to relieve the requirement for ground-based range safety initiation, and allow a more predictable and reliable means for accommodating a stray nanolauncher operating out of a launch site.

In addition, we looked at how miniaturization of navigation and computer components, even if sacrificing some degree of precision, could help reduce the number of separately designed, tested, produced, and installed avionics boxes and their interconnections. Doubling the number of avionics components adds cost and time on the nonrecurring side of life cycle costs, as well as bloats the amount of work and reduces the responsiveness in recurring production and launch site operations. Also, the likelihood of a more burdensome supply chain emerges. On the other hand, technologies that enable substantial reductions in avionics box count would have the opposite, beneficial effect.

The team created a Functional System Breakdown Structure (F-SBS) as a guide to isolate and quantifiably compare differing avionics technologies within the NL001 system.

The F-SBS was very similar to the ACT Pedigree used in Phase I, but organized the functional classifications associated with the subsystems and their major components and assemblies. After a short effort to build a spreadsheet tool (SBS_Tool.xlsm) which automatically created system descriptions that itemize the components and assemblies of the defined subsystems, a new F-SBS System Definition Sheet was created for NL001 with baseline avionics (Appendix D), and another was created with advanced integrated avionics technology (Appendix E) that dramatically reduced the avionics box count. (Note: While Appendices D and E provide subsystem component/assembly information, Appendix F provides greater functional detail. The functions assigned are not necessarily associated one-for-one with a particular component, but rather assignments were based on the dominant function.)

A functional diagram of the baseline avionics architecture for NL001, which was used in constructing the system definition sheet in Appendix D, is presented in Figure 17 and Figure 18. Three avionics architecture assumptions were assumed for the life cycle analysis. First was the status quo case, in which business-as-usual designs produce a number of dedicated boxes supplied by a variety of aerospace vendors providing existing (2014) flight-certified items, as for example, those used in modern sounding rockets. Second was COTS-derived avionics architecture, which assumes existing technologies, but requires fight certification. This offers the promise of reduced avionics components, as well as miniaturization of existing components. The other architecture considered is advanced integrated avionics, where the design focus is on using advancements in electronics and power storage to dramatically reduce the number of separately designed, fabricated, tested, and installed avionics devices—including those that perform flight safety system functions.

2.5.2 Avionics Technology

Specific avionics technology needs include the following:

- Substantial reduction in production-line-installed/field-removable electronic boxes
- Substantial reduction in number of separately handled electrical and electronic connectors, harnesses, and cables
- Hardware, software, and algorithms in compliance with the Range Commander's Council and their Range Safety Group and Flight Termination Systems Subcommittee standards, such as the following:
    - AFTS RCC 319-07, Flight Termination Systems Commonality Standard
    - AFTS RCC 324-01, Global Positioning and Inertial Measurements Range Safety Tracking Systems' Commonality Standard
    - AFSPCMAN 91-710, Range Safety User Requirements Manual
- *Certified mature* avionics components and assemblies that are connected up in launch configuration. These avionics contain actual flight software communicating with ground architectural elements, and they have successfully flown the minimum number of flights required to produce documented, statistically significant confidence in the maturity of the technology (e.g., thermal/vibration, salt fog, corona, lightning strike, and fault tolerance).

A typical integrated avionics system (four-stage all solid N/L) is shown in Figure 19.

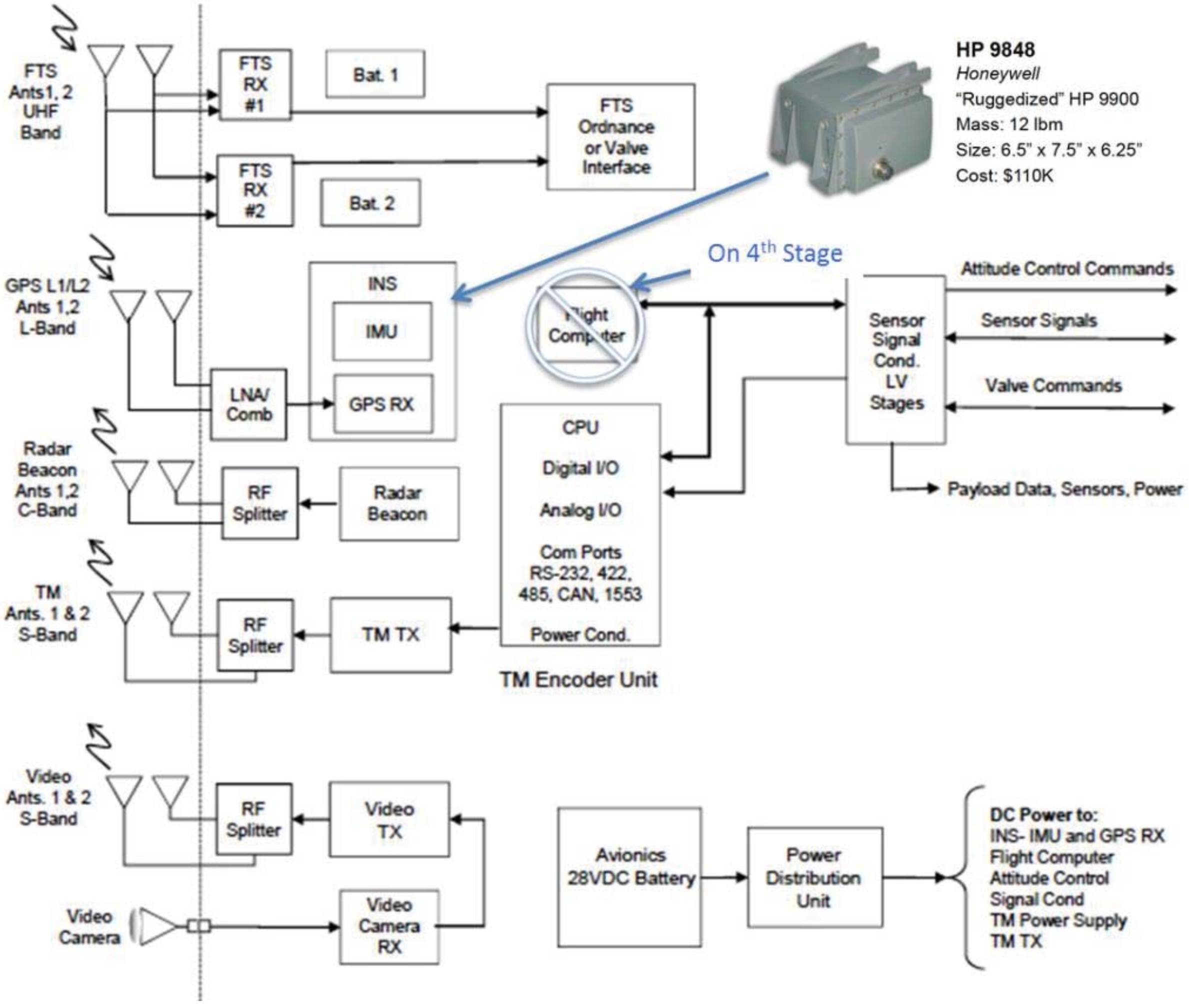


Figure 17. Concept for NL001 3rd Stage Avionics Architecture

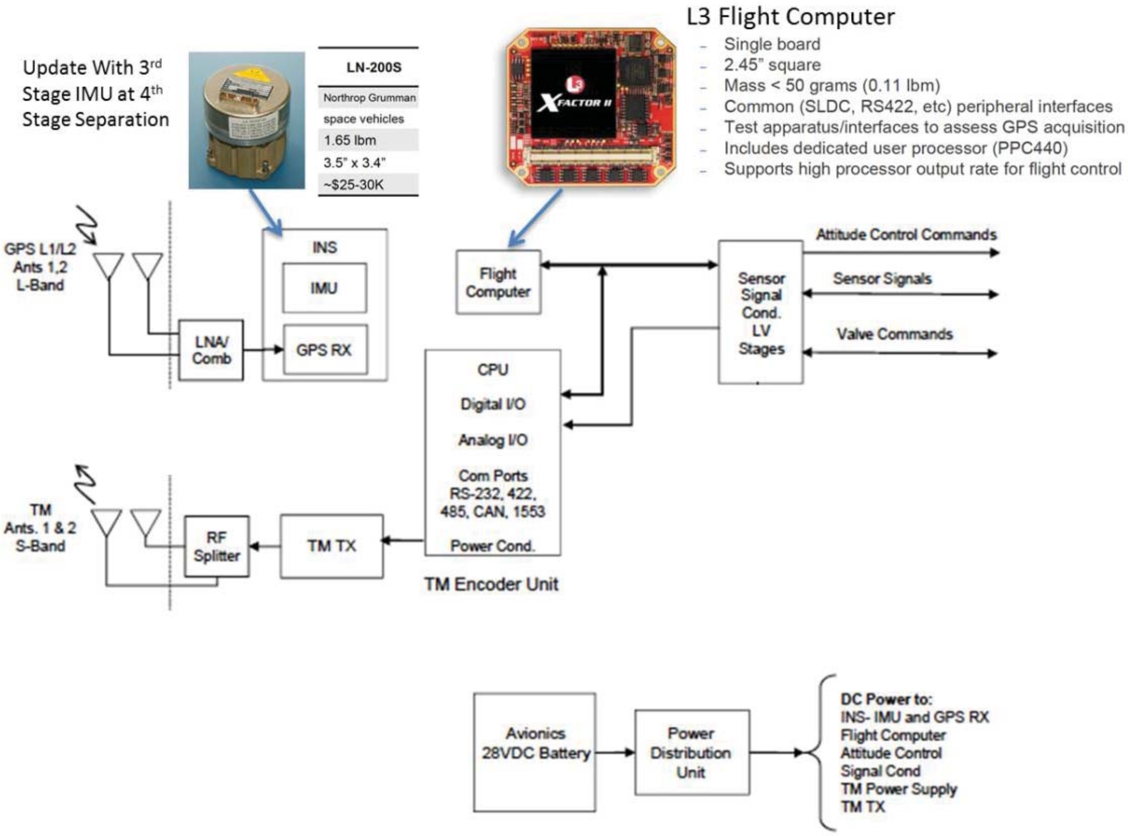


Figure 18. Concept for NL001 4th Stage Avionics Architecture

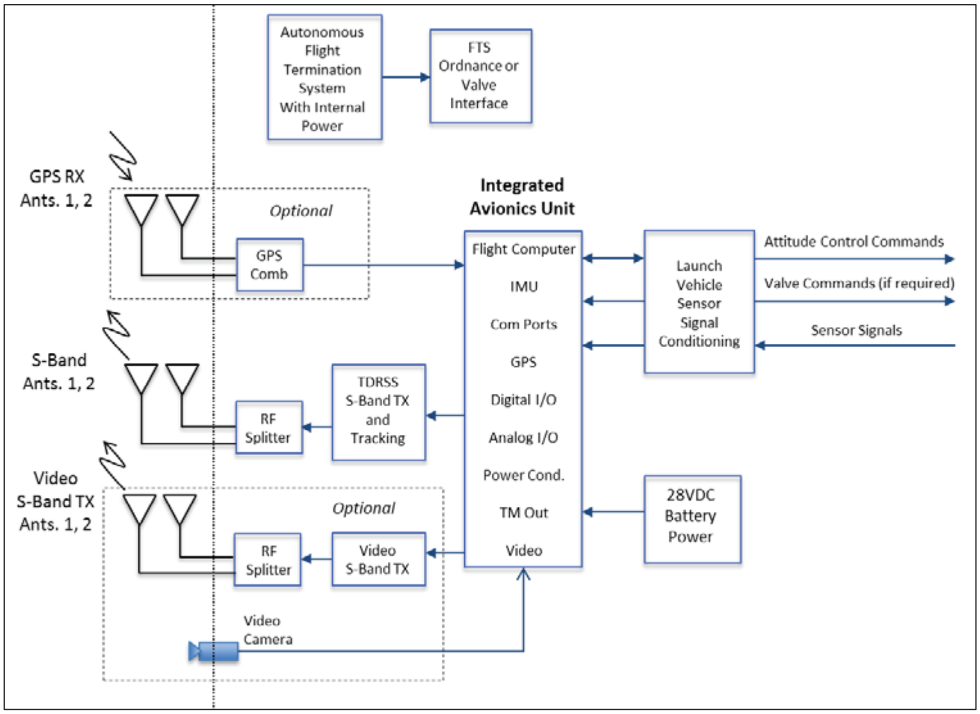


Figure 19. Example Advanced Integrated Avionics Architecture

2.5.3 Comparing the Architectural-Level Impacts of Integrated Avionics

The refined NL001/all-solid functional definition, including avionics functions, was compatible with Langley's performance analysis. The new functional definition was also flexible enough to use in other analyses (such as the Skylon assessment also performed in ALTIA in 2014). A comparison of the index values that resulted from the Phase I/ACT Pedigree definition sheet and the Phase II F-SBS System Definition Sheet are in Table 6, along with the results for NL001 with Advanced Integrated Avionics architecture.

Table 6. Phase I and II Index Results for Life Cycle Comparisons

Vehicle	System Count Index	Total Interface/Interconnections Complexity Index	Normal Interface/Interconnections Complexity Index	Toxic Interface/Interconnections Overhead Index	Ordnance Interface/Interconnections Overhead Index	Confined Spaces Interface/Interconnect. Overhead Index
Phase I NL001 (Using 2013 ACT Pedigree)	111	344	302	0	42	0
Phase II NL001 Baseline Avionics Technology (Using 2014 F-SBS Definition)	110	356	305	0	51	0
Phase II NL001 Integrated Avionics Technology (Using 2014 F-SBS Definition)	97	285	243	0	45	0

2.6 Comparison 2 Results

2.6.1 Result 5 – Avionics Can Provide Substantial Cost and Productivity Improvement

As Table 6 shows, a reduction in avionics component counts was achieved through specifying a highly functional, integrated avionics box in the top stage—in particular, one that houses a miniature inertial measurement unit,[4] flight computer, radio-frequency (RF) communications, and redundant/fault-tolerant switching of AFSS functional paths.

When running the most aggressive of the three business case assumptions in ACT, the integrated avionics technology reduced the incremental and the average launch costs at 12 flights per year by ~20% (Figure 20).

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[4] Specifically, a MEMS IMU, or "microelectromechanical systems" (MEMS) inertial measurement unit (IMU).

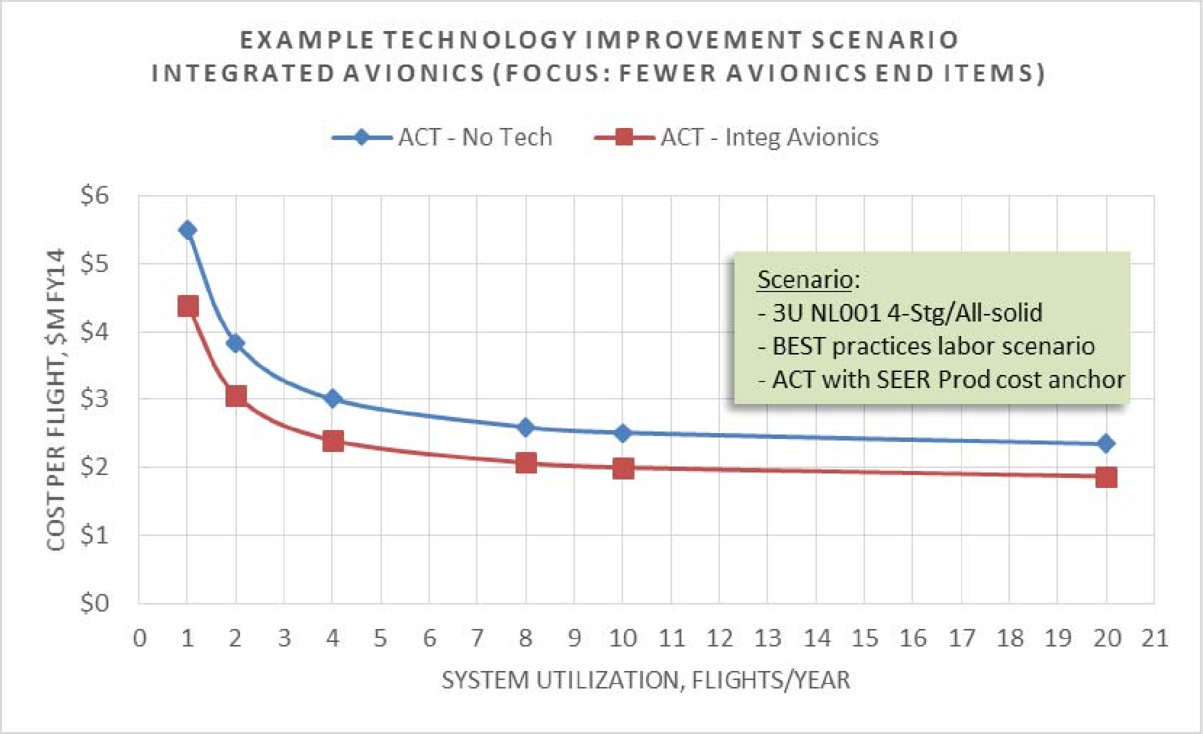


Figure 20. ACT Screenshot Comparing Nanolaunchers With and Without Integrated Avionics

2.6.2 Result 6 – Other Concept and Technology Improvement Strategies

Other nanolauncher system concepts beyond the NL001/all-solid configuration and other technologies were identified for examination by the team. These included subsonic air-launched concepts, additive fabrication techniques, solid motor production innovation, and lightweight materials. However, time and resource constraints did not allow the ALTIA team to investigate these further.

2.7 Conclusions

2.7.1 Conclusion 1 – Infrastructure Accumulation Must Be Constrained by Design

Very low launch costs severely restrict the amount of fixed infrastructure and annual work that can accumulate. The largest cost contributor is fixed recurring production costs.

2.7.2 Conclusion 2 – Minimum Acceptable System Utilization Must Be Identified

Realizing low launch costs requires achieving more than a threshold limit of system utilization, below which customer costs are rapidly raised. It is a seemingly obvious conclusion, but one worth stating—and should be of interest to both business and engineering organizations. Often unknowingly, by accumulating many compromises during the design, development, test, and evaluation (DDT&E) phases, system utilization takes a back seat to a “hurry things along and just make it work” approach. In the end, the nanolauncher result cannot be just another way to reach orbit. Rather, it must demonstrate to a customer base ready to find alternatives that nanolaunchers have achieved greater delivery flexibility at acceptable prices.

2.7.3 Conclusion 3 – Element and Subsystem Complexity Drives Life Cycle Result

Controlling the complexity of the total architectural outcome must be of equal or greater importance as flight performance at the earliest phase of development.

The number of flight and ground elements, subsystems, and components across the production and operations architecture must be identified, budgeted, managed, and controlled, and demonstrated to achieve the expected operational cost, responsiveness, and dependability originally advertised.

2.7.4 Conclusion 4 – Integrated Avionics Simplifies Design and Use of Nanolaunchers

Integrated avionics technology can substantially reduce the recurring cost per flight and potentially improve the launch rate capability. However, advances in avionics that do not dramatically reduce the number of procured and installed avionics components do not realize significant cost and productivity benefits.

2.7.5 Conclusion 5 – Technology Investments Can Better Enable $2M Flights

While the integrated avionics in and of itself allows nanolaunchers to conceivably achieve $2M per flight—the outside limit of the affordability objective—it is clear that other technology investments which simplify flight and ground system designs can help lower fixed and variable costs even further. Also, it should be noted that if programmatic or commercial business means can be found to alleviate and share the fixed-cost burdens, then the variable cost per flight is a fraction (50% in the ACT analysis runs) of the total annualized average cost per flight—allowing the possibility of lower nanosat customer prices.

2.7.6 Conclusion 6 – Specialization of Infrastructure and Operations

Delivery of payloads needing routine, low-cost, highly available service should be separated from other nonroutine activities needed for engineering tests and less-urgent science applications.

2.8 Findings

The findings documented in this section are derived from the previous results and conclusions. They cover either technical, or programmatic business aspects, or both.

2.8.1 Finding 1 – Minimize the infrastructure and use the system at a higher flight rate

The requirement for users to own dedicated facilities and equipment and to routinely use expensive services will be minimized or avoided, as this rapidly accumulates fixed annual costs. To do so requires (1) engineering and technology effort to eliminate these requirements by design, and (2) rearrangement of business functions to minimize requirements that remain following the design, development, and certification efforts. The accumulation of assets and services not adding value to the objective of routinely producing simple nanolauncher flights should be of high interest to technologists and business managers alike.

2.8.2 Finding 2 – Pursue focused nanolauncher technologies and design approaches, such as integrated avionics and a three-stage nanolauncher.

Trading many avionics units for a single integrated avionics unit is a specific technology investment that can reduce the fixed annual avionics support costs, production costs, and improve production and ground operations cycle times. Pursuing other technologies that provide the same benefits (additive manufacturing of solid stages, for example, might also be pursued). The extremely compact four-stage all-solid nanolauncher might be traded with alternative designs; such as a simpler, larger three-stage version. This is likely to result in streamlined production infrastructure, and an overall lower level of both acquisition and recurring annual labor and material costs. In general, the goal is to create architectures with the lowest cumulative (1) bill of materials and supply chain complexity, (2) production and fabrication assets, (3) assembly, handling, and support equipment, and (4) support work tasks and required annual services.

When running ACT with a theoretical three-stage version of NL001—by removing the second-stage complexity, for instance, but retaining the subsystem functionality and complexity needed for the first stage and the upper stage, a 15%–20% reduction in annualized cost per flight is estimated. Even if the vehicle grows in length and mass, the differences in the life cycle costs should be negligible at this scale of application.

When combined with integrated avionics technology, a 40% reduction, down to a $1.6M per flight average cost, and a $700K incremental cost per flight is estimated. ACT also estimates an equivalent increase in production and launch rate capability. While not explored in great detail, a cumulative reduction of 14% of nonrecurring costs is also indicated (Table 7).

Table 7. Comparison of Results with Theoretical Three-Stage N/L Version

Vehicle	System Count Index	Total Interface/ Interconnections Complexity Index	Normal Interface/ Interconnections Complexity Index	Toxic Interface/ Interconnections Overhead Index	Ordnance Interface/ Interconnections Overhead Index	Confined Spaces Interface/ Interconnect. Overhead Index
Phase II NL001 Baseline Avionics Technology (Using 2014 F-SBS Definition)	110	356	305	0	51	0
Phase II NL001 Integrated Avionics Technology (Using 2014 F-SBS Definition)	97	285	243	0	45	0
Proposed Phase III NL001/All-solid Three-Stage	92	309	265	0	44	0
Proposed Phase III NL001/All-solid Three-Stage w/Integrated Avionics	79	238	203	0	38	0

2.8.3 Finding 3 – "Express Lanes" and "Flex Lanes" for Nanolaunchers can better organize life cycle costs to support the industry

Separating the operation and management of the dedicated small-sat delivery infrastructure—both production and launch operations is a potential business or program arrangement found to address many of the technical and financial barriers to the growth of a successful nanolauncher industry. By doing so it allow the creation of nanosat delivery *express lanes* (Figure 21), unencumbered by other custom fabrication and time-consuming launch preparations, which would occur in separately managed sets of assets, or *flex lanes* (Figure 22).

In an effort to keep up-front acquisition and recurring costs low, a business operation will often create only a single line of production and launch operations assets, such as launchers and launch pads. This, however, forces the entire customer base to queue in single-file fashion through the same set of production and launch operations assets. Particularly for those commercial space customers who have simple requirements, and who often need quick, on-schedule deliveries to achieve their time-to-market business plans, waiting on the custom/unique requirements of the payload or launch vehicle configuration in front of them is not acceptable.

Acceptable alternatives in the industry are hard to come by, however. The emerging dedicated small launcher industry affords the opportunity to begin untangling simple, routine production and launch activities from the occasional complex ones needed for space science and technology research and demonstration. Both sets of customers need to be accommodated. It is not necessary that they get in each other's way and restrict the nanosat market. It is not evident from our investigations that anything other than the traditional model of comingling is being considered in the near term.

By allowing two sets of assets to be separately owned and operated, highly affordable and responsive “express lanes” can achieve the cost goals desired. In addition, the nonroutine assets can focus on continuous improvements, and production and operations demonstrations, as well perform necessary certifications. If these innovations are proven off-line, then long-term periodic downtimes of the *express lane* assets can allow them to be quickly modified and benefit from the improvement with far less risk than today’s single-string tendencies.

The separate express and flex lane approach also provides an opportunity to help emerging small businesses that are focused on serving either the manufacturers or the operators of space transportation systems. In current business structures, the manufacturer of a space transportation system is also typically its operator, but as the space transportation industry matures, the manufacturer and operators may be different organizations (as seen in the air, marine, and rail transportation industries).

It would appear that NASA, the U.S. government, and private industry have an opportunity to overcome technical and business risks for nanolaunchers in the near term with relatively little investment, by quickly establishing small-sat express lanes to space. It would directly address the question *“why does it take so long and cost so much to fly a kilogram to orbit?”*

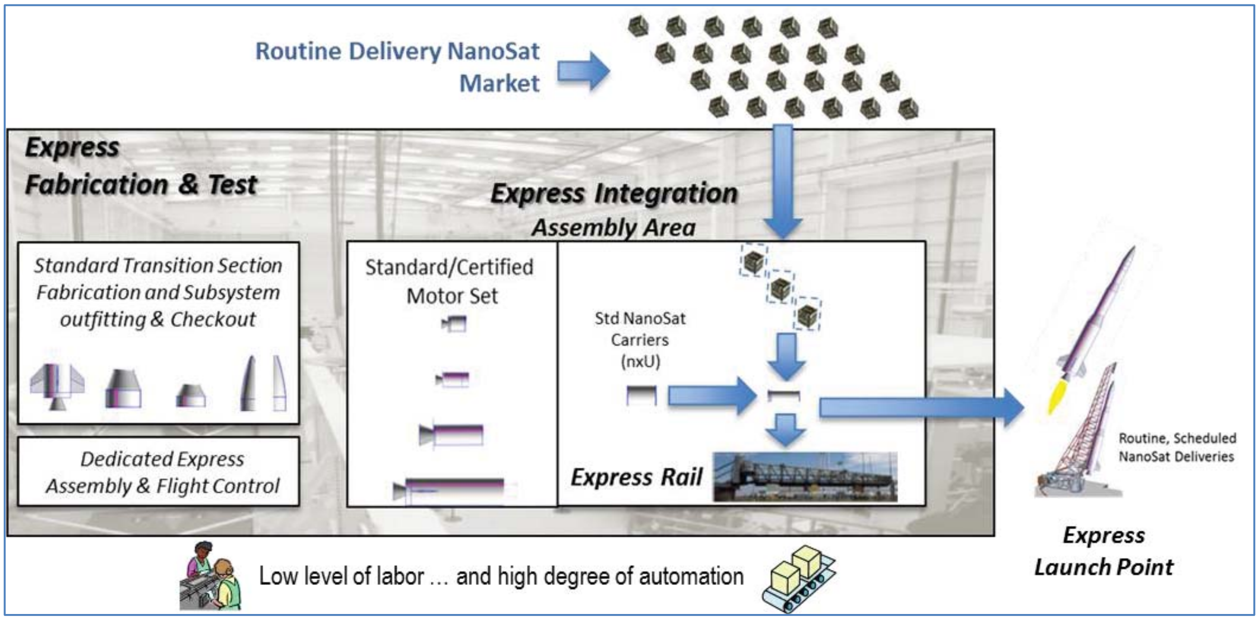


Figure 21. **Concept of Limited-Service, Highly Responsive Nanolauncher “Express Lane”**

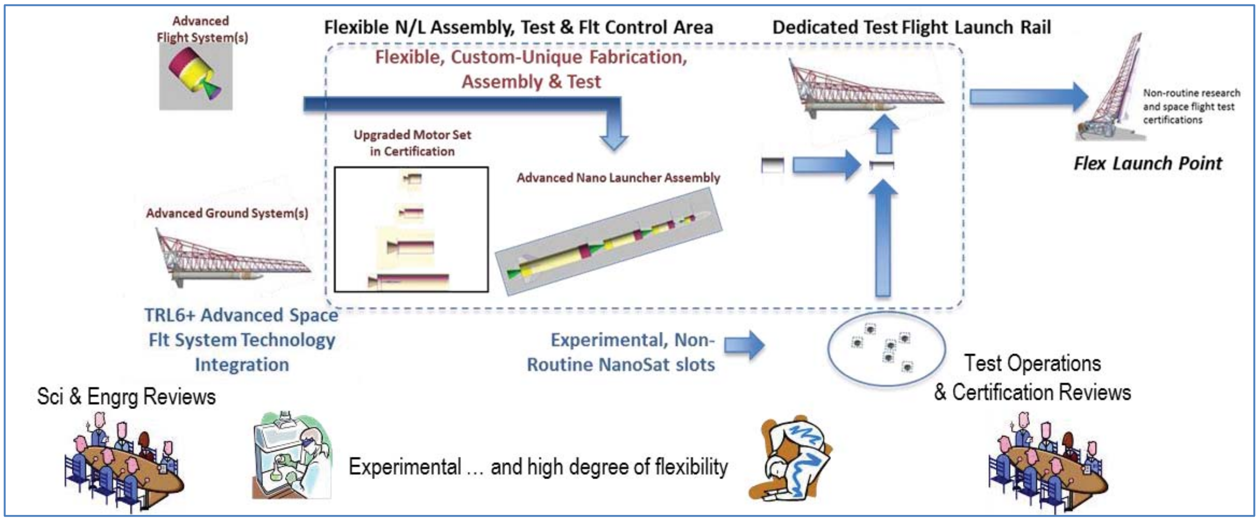


Figure 22. Full-Service "Flex Lane" for Integrating Technologies and Certifying New Processes

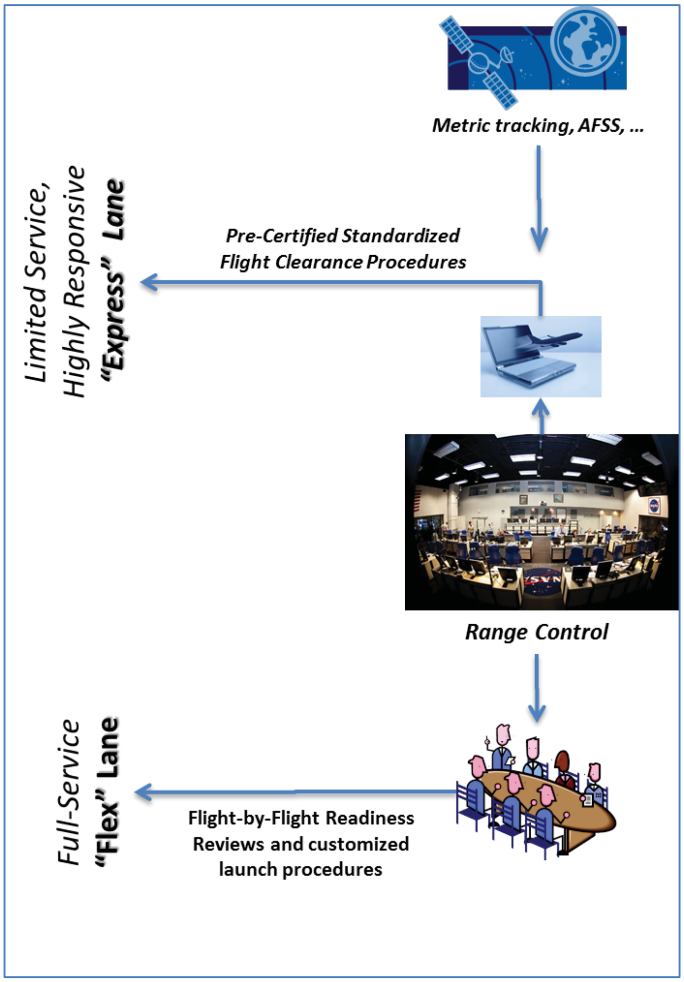


Figure 23. Modes of Range Control for Express and Flex Ops and Infrastructure

3 SKYLON QUICK-LOOK ASSESSMENT

This work was performed for the Langley Research Center Vehicle Analysis Branch SABRE/Skylon assessment task leader (Mr. R. Lepsch). Because of the proprietary nature of the data handled in this assessment, the results are provided to NASA LaRC under separately controlled documentation.

4 DEVELOPMENT OF A FUNCTIONAL SYSTEM BREAKDOWN STRUCTURE (F-SBS)

A common means for defining flight and ground systems for both performance and life cycle analysis—an SBS Tool—was developed during the course of performing the ALTIA work.

Methods for defining and organizing advanced spaceflight systems have traditionally used weight statements as a starting point in conceptual design. Handbooks and guideline material are available and quite useful for defining flight vehicle weights and performance evaluations.

These well-documented methods, while useful in optimizing system flight performance, have been found to be less useful in achieving architectural designs that optimize broader life cycle attributes, such as total system affordability, responsiveness, and productivity. In addition, comparing the impact of a space vehicle technology on affordability or productivity, for example, is not easily discerned from mass properties alone. For example, the level of effort involved in software coding and maintenance are not directly correlated to vehicle mass.

Life cycle attributes, such as affordability, are often more a function of the extent to which ground systems or production infrastructure is required. Yet, much of this infrastructure is implied through the many subsystems and commodities specified in a space vehicle's weight statement.

What is needed during early concept trades and analysis is a structured catalog of functions for defining flight systems, ground systems, and production systems. This could be used to uniformly address the flight vehicle architecture, the ground support architecture, as well as any recurring production or logistical systems and infrastructure. The result is a system description of how proposed spaceflight architectures fulfill the needs of an operational service, system by system, as opposed to a simpler list of vehicle objects to be procured, manufactured, and for expendables, consumed.

For NASA technologists, the concern is whether a technical investment can or should be made to improve spaceflight architectures—regardless of who designs, produces, or operates the system. In order to make judgments of this scale, it is necessary to put proposed technology solutions within a comprehensive architectural context and assess not only impact on flight system performance, but also impact (both positive and negative) on producibility and operability. The earlier the totality of a concept with a technology change is captured and understood, the more likely the technology investment will succeed in providing an improvement.

In order to better support various advanced concept and technology impact assessments, NASA's Langley Research Center and the Kennedy Space Center collaborated on the kind of comprehensive functional Systems Breakdown Structure (SBS) needed for such impact assessments of advanced launch technology.

Preliminary use of the SBS described here has revealed that it may have wide application for space systems in general, and therefore, may have potential application by other engineers and technologists.

4.1 Technical Approach and Scope for a Functional Breakdown

The approach used to organize this functional system breakdown structure is similar to other methods. It differs somewhat, however, in that there are a number of dimensions to the structure (Figure 24). One aspect is a structure for addressing a comprehensive set of spaceflight architectural *functions* (the generalized *verbs* performed by the system), and another being a structure for specifying the *parts* of the design (the design- or concept-specific objects or *nouns* of the system). In addition, the architectural characteristics of each can be used to discriminate tradeoffs between design choices. These *figures-of-merit* may include mass properties, volume, and part reliability in flight for performance analysis; and toxicity, pyrotechnic hazard characteristics, and other such characteristics that, collectively, affect the operational *attributes* of affordability, responsiveness, and maintainability.

The scope of the Functional SBS (F-SBS) is to provide a methodology for specifying the design and estimating its characteristics. The ACT algorithms implement the methods and techniques for comparing different systems and conducting tradeoffs, while the SBS Tool builds the input data for ACT to compare.

Section 4.2 defines a generic functional framework of *space vehicles* for a conceptual system definition (i.e., specifying a space vehicle concept). Often, a functional definition ends when most of the mass is perceived to have been accumulated. However, in terms of the operability, supportability, and dependability of a flight system, certain system functions specified in the early conceptual design phase may have profound effects on production and operation.

In Section 4.3, the architecture is defined for the various functional ground stations and sets of equipment, networks, or services that necessarily follow from the definition of the flight systems. Similarly, *ground station sets*, then, are somewhat equivalent to the stages and elements of a flight system in that each are generally composed of various subsystems. These ground subsystems may handle propellants, manage thermal loads, transport electric power, or provide information flow. These subsystems may, for example, be used for vehicle assembly and integration, spacecraft servicing of fluids and propellants, payload packaging, or perhaps more than one of these operations.

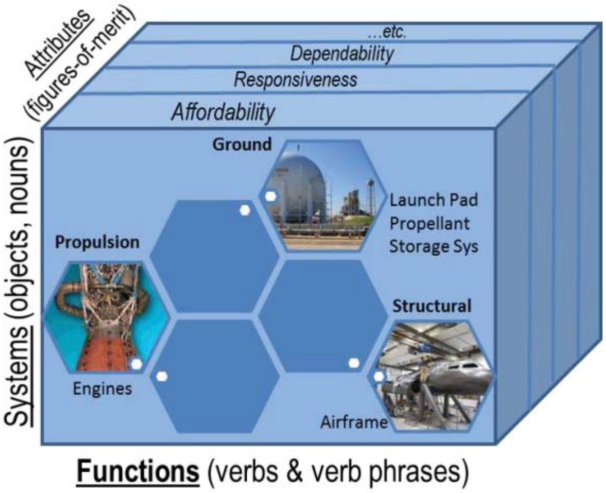


Figure 24. Dimensions of Architecture

Future work will round out the SBS with (1) production, (2) logistics functions, and (3) the program business elements of the architecture.

Once the flight and ground elements and subsystems have been defined to roughly equivalent levels of detail, figures of merit can characterize each part of the architecture. Spaceflight concepts will not only estimate mass and vehicle configuration, but also a much more comprehensive and rounded-out architecture right from the start of the conceptual analysis and design phase.

4.2 Functional Breakdown for Spaceflight Architectures (Top Levels)

In this section, the generic functional hierarchy is described in further detail. First, the top-level functions of the architecture (i.e., terms *A*, *B,* and *C*) are described. Next, in order, the four architectural segments (flight, ground, production, and business) are described. Note: As previously mentioned, this document does not address the third and fourth segments; i.e., the production and business functions in detail.

4.2.1 Level A – Spaceflight Architecture Functional Codes

For the Advanced Launch Technologies Impact Assessment (ALTIA) effort, the Level A F-SBS options for generic architectural level definition are as follows:

A1 = Suborbital – ballistic
A2 = Suborbital – point-to-point
A3 = Earth-to-orbit (ETO)
A4 = Earth-orbit transfer
A5 = Interplanetary transfer
A6 = Lunar-planetary surface transfer

4.2.2 Level B – Spaceflight Architectural Class Codes

For the ALTIA effort, the Level B F-SBS codes for generic architectural classes are as follows:

B1 = Suborbital – sounding
B2 = Suborbital – point-to-point
B3 = Small-lift ETO class (<2 mt)
B4 = Medium-lift ETO class (2–20 mt)
B5 = Heavy-lift ETO class (20–50 mt)
B6 = Super-heavy lift ETO class (>50 mt)
B7 = Earth-orbiting crew transfer
B8 = Earth-orbiting cargo transfer
B9 = Earth-orbiting crew and cargo transfer
B10 = Earth-orbiting cargo transfer
B11 = Interplanetary crew transfer
B12 = Interplanetary cargo transfer
B13 = Interplanetary crew and cargo transfer
B14 = Lunar-planetary crew surface transfer
B15 = Lunar-planetary cargo surface transfer

B16 = Lunar-planetary crew and cargo surface transfer

4.2.3 Level C – Spaceflight Architectural Segment Codes

The architectural segment codes, as previously described, are simply defined by the four architectural segments, as follows:

C1 = Flight Segment – flight system (vehicle) functions; launch vehicle, spacecraft, etc.
C2 = Ground Segment – launch and landing site ground system functions
C3 = Production Segment – manufacturing, fabrication, and production system functions
C4 = Business Segment – business (or government program) integration functions

4.3 Spaceflight Vehicle Segment Functional Codes

This section provides the functional coding schema for the vehicle/flight systems segment of the spaceflight architecture. The list here was developed and used during the ALTIA effort in FY14, and is planned to be reviewed and published in more detail and description in FY15 by KSC and Langley partners.

4.3.1 Level D – Spaceflight Vehicle Element Functional Codes

For the ALTIA effort, the Level D F-SBS codes for generic spaceflight vehicle elements are as follows:

D1 = Ascent primary thrusting – ground-lit
D2 = Ascent parallel thrusting – ground-lit
D3 = Ascent thrusting – tandem air-lit
D4 = Ascent thrusting – tandem vacuum-lit
D5 = Ascent thrusting – tandem vacuum-lit w/payload deploy
D6 = External propellant storage for ascent
D7 = Externalized cargo enshroudment/carrying
D8 = Spacecraft – cargo delivery only (pressurized only)
D9 = Spacecraft – unpressurized payload delivery only
D10 = Spacecraft – cargo delivery only (pressurized and unpressurized)
D11 = Spacecraft – extended flight for crew and cargo
D12 = Spacecraft – crew delivery only
D13 = Spacecraft – crew and cargo delivery
D14 = Spacecraft – spacecraft service and propulsion
D15 = Spacecraft – docking
D16 = Multifunctional – spacecraft and ascent/descent functions

4.3.2 Level E – Spaceflight Vehicle Element Subsystem Discipline Codes

For the ALTIA effort, the Level E F-SBS codes for generic spaceflight vehicle subsystem disciplines are as follows:

E1 = Structural containment and support
E2 = Vehicle stability and control

E3 = Main propulsion
E4 = Auxiliary propulsion
E5 = Electrical power generation, control, and distribution
E6 = Mechanical power generation, control, and distribution
E7 = Thermal protection
E8 = Environmental and thermal control
E9 = Command and data management
E10 = Communications and tracking
E11 = Guidance and navigation (G&N)
E12 = Flight termination and abort mode switching
E13 = Flight crew interfacing
E14 = External lighting
E15 = Stage/element separation
E16 = Launch/takeoff and landing support
E17 = Personnel accommodation
E18 = Payload accommodation (vehicle internalized)

4.3.3 Level F and G – Spaceflight Element Subsystem Function/Subfunction Codes

For the ALTIA effort, the Level F and G F-SBS codes for generic spaceflight vehicle subsystems are defined in this section and organized by the appropriate Level E discipline.

4.3.3.1 Structural Containment and Support Function/Subfunction Codes

For the ALTIA effort, the F-SBS codes for generic structural containment and support functions are defined as follows:

E1.F1 = Body/framework function – contain vehicle functions and support structural loads
E1.F1.G1 = Body/framework compartmentalization
E1.F1.G2 = Thrust transmittal

E1.F2 = Non-body/framework functions – attachment to body/framework
E1.F2.G1 = Non-body/framework compartmentalization (placeholder)

E1.F3 = Enclose payload
E1.F3.G1 = Payload enclosure (placeholder)

E1.F4 = Enclose crew/passenger
E1.F4.G1 = Flight crew station structural enclosure
E1.F4.G2 = Passenger structural enclosure

E1.F5 = Connect and attach elements
E1.F5.G1 = Flight-to-flight structural connection and attachment
E1.F5.G2 = Flight-to-ground structural connection and attachment

4.3.3.2 Level F – Vehicle Stability and Control Subsystem/Subfunction Codes

For the ALTIA effort, the F-SBS codes for generic vehicle stability and control subsystems are defined as follows:

E2.F1 = Aerodynamic stability and control (including structural surface, hinge line sealing, and actuation)
E2.F1.G1 = Aerodynamic lift generation (e.g., structural implementation through wings)
E2.F1.G2 = Aerodynamic vehicle stabilization and/or control
E2.F1.G3 = Dedicated drag generation and control (not combined with other aerosurface function)

E2.F2 = Vehicle thrust vector control (TVC)
E2.F2.G1 = Gimbaled actuation thrust vector control
E2.F2.G2 = Fluid injection/flow separation thrust vector control
[Note: for differential throttling, see "Propulsion system control and health management"]

E2.F3 = Vehicle reaction control and stabilization
E2.F3.G1 = Reaction control propellant fill and drain
E2.F3.G2 = Reaction control propellant storage and containment
E2.F3.G3 = Reaction control propellant antigeysering
E2.F3.G4 = Reaction control propellant tank feed to power plant
E2.F3.G5 = Provide reaction control propellant bleeding (for thermal conditioning)
E2.F3.G6 = Reaction control propellant bubbling (for thermal conditioning)
E2.F3.G7 = Reaction control propellant circulation (for thermal conditioning)
E2.F3.G8 = Reaction control propulsion purging (for contaminant removal)
E2.F3.G9 = Reaction control propulsion pressurization (to maintain NPSH)
E2.F3.G10 = Combustor delivery (pumping/pressure transfer) for reaction control
E2.F3.G11 = Preburning (supply pump turbine drive) for reaction control
E2.F3.G12 = Starting/ignition for reaction control
E2.F3.G13 = Reaction control combustion (i.e., injecting, mixing, molecular/subatomic reacting, and containment)
E2.F3.G14 = Reaction control nozzle/exhaust gas management (expulsion/expansion of combustion products)
E2.F3.G15 = Combustion shutdown management (i.e., cooling and control)
E2.F3.G16 = Reaction control propellant acquisition and storage management (instrumentation and control)
E2.F3.G17 = Reaction control propellant flow and thrust interaction (pogo suppression)
E2.F3.G18 = Reaction control propellant acquisition and settling
E2.F3.G19 = Reaction control propellant subcooling/densification
E2.F3.G20 = Reaction control propulsion system sensor data collection and signal conditioning
E2.F3.G21 = Reaction control propulsion system command reaction control processing and fluid/mechanical control
E2.F3.G22 = Flow-path-induced electromechanical power takeoff (e.g., ullage or shaft-powered takeoff)

E2.F3.G23 = Hardware contamination flush/purging for start/restart
E2.F3.G24 = Supply reaction mass for vehicle stability and control
E2.F3.G25 = Supply reaction mass bias/margin for vehicle stability and control
E2.F3.G26 = Supply medium/media(s) for purging
E2.F3.G27 = Supply medium/media(s) for main propulsion pressurization
E2.F3.G28 = Supply medium/media(s) for main propulsion ullage

E2.F4 = Vehicle spin stabilization (and/or de-spin)
E2.F4.G1 = Propulsive vehicle spin-up (and/or de-spin)
E2.F4.G2 = Nonpropulsive spin-up/de-spin

E2.F5 = Landing and alighting control
E2.F5.G1 = Vehicle ground deceleration, skid control and steering
E2.F5.G2 = On-ground steering control only

4.3.3.3 Level F – Main Propulsion Subsystem/Subfunction Codes

For the ALTIA effort, the F-SBS codes for generic main propulsion subsystems are defined as follows:

E3.F1 = Main propellant storage and distribution
E3.F1.G1 = Main propellant fill and drain
E3.F1.G2 = Main propellant storage and containment
E3.F1.G3 = Main propellant antigeysering control
E3.F1.G4 = Main propellant tank feed to power plant

E3.F2 = Main propulsion thermal conditioning for ignition/start-up
E3.F2.G1 = Provide main propellant bleeding
E3.F2.G2 = Main propellant bubbling
E3.F2.G3 = Main propellant circulation

E3.F3 = Main propulsion purging and pressurization
E3.F3.G1 = Main propulsion purging (for contaminant removal)
E3.F3.G2 = Main propulsion pressurization (to maintain NPSH)

E3.F4 = Air intake/inlet management for main propulsion
E3.F4.G1 = Forward shock/compression control for main propulsion
E3.F4.G2 = Inlet precooling, heat exchange, etc., for main propulsion
E3.F4.G3 = Liquefaction for main propulsion
E3.F5 = Main thrust generation/power plant function
E3.F5.G1 = Main combustor delivery (pumping/pressure transfer)
E3.F5.G2 = Pre-burning (supply pump turbine drive) for main propulsion
E3.F5.G3 = Starting/ignition for main propulsion
E3.F5.G4 = Main combustion (i.e., injecting, mixing, molecular/subatomic reacting, and containment)
E3.F5.G5 = Main propulsion nozzle/exhaust gas management (expulsion/expansion of combustion products)

E3.F5.G6 = Main combustion shutdown management (i.e., cooling and control)

E3.F6 = Main propellant flow path management
E3.F6.G1 = Main propellant acquisition and storage management (instrumentation and control)
E3.F6.G2 = Main propellant flow and thrust interaction (pogo suppression)
E3.F6.G3 = Main propellant acquisition and settling
E3.F6.G4 = Main propellant subcooling/densification
E3.F6.G5 = Main propulsion system sensor data collection and signal conditioning
E3.F6.G6 = Main propulsion system command main processing and fluid/mechanical control
E3.F6.G7 = Differential main propulsion throttling for actuating vehicle stability and control
E3.F6.G8 = Main propulsion flow-path-induced power takeoff (e.g., ullage or shaft-powered takeoff)
E3.F6.G9 = Hardware contamination flush/purging for main propulsion start/restart

E3.F7 = Supply main onboard reaction mass
E3.F7.G1 = Supply main reaction mass
E3.F7.G2 = Supply main reaction mass bias/margin

E3.F8 = Supply fluid/gas medium/media(s) for main propulsion purge, pressurization, and flow path control
E3.F8.G1 = Supply medium/media(s) for purging
E3.F8.G2 = Supply medium/media(s) for main propulsion pressurization
E3.F8.G3 = Supply medium/media(s) for main propulsion ullage
E3.F8.G4 = Supply fluid/gas medium/media(s) for propulsion control

4.3.3.4 Level F – Auxiliary Propulsion Subsystem/Subfunction Codes

For the ALTIA effort, the F-SBS codes for generic auxiliary propulsion subsystems are defined as follows:

E4.F1 = Auxiliary propellant storage and distribution
E4.F1.G1 = Auxiliary propellant fill and drain
E4.F1.G2 = Auxiliary propellant storage and containment
E4.F1.G3 = Auxiliary propellant antigeysering control
E4.F1.G4 = Auxiliary propellant tank feed to power plant

E4.F2 = Auxiliary propulsion thermal conditioning for ignition/start-up
E4.F2.G1 = Provide auxiliary propellant bleeding
E4.F2.G2 = Auxiliary propellant bubbling
E4.F2.G3 = Auxiliary propellant circulation

E4.F3 = Auxiliary propulsion purging and pressurization
E4.F3.G1 = Auxiliary propulsion purging (for contaminant removal)
E4.F3.G2 = Auxiliary propulsion pressurization (to maintain NPSH)

E4.F4 = Air intake/inlet management for auxiliary propulsion
E4.F4.G1 = Forward shock/compression control for auxiliary propulsion
E4.F4.G2 = Inlet precooling, heat exchange, etc., for auxiliary propulsion
E4.F4.G3 = Liquefaction for auxiliary propulsion

E4.F5 = Auxiliary thrust generation/power plant function
E4.F5.G1 = Auxiliary combustor delivery (pumping/pressure transfer)
E4.F5.G2 = Preburning (supply pump turbine drive) for auxiliary propulsion
E4.F5.G3 = Starting/ignition for auxiliary propulsion
E4.F5.G4 = Auxiliary combustion (i.e., injecting, mixing, molecular/subatomic reacting, and containment)
E4.F5.G5 = Auxiliary propulsion nozzle/exhaust gas management (expulsion/expansion of combustion products)
E4.F5.G6 = Auxiliary combustion shutdown management (i.e., cooling and control)

E4.F6 = Auxiliary propellant flow path management
E4.F6.G1 = Auxiliary propellant acquisition and storage management (instrumentation and control)
E4.F6.G2 = Auxiliary propellant flow and thrust interaction (pogo suppression)
E4.F6.G3 = Auxiliary propellant acquisition and settling
E4.F6.G4 = Auxiliary propellant subcooling/densification
E4.F6.G5 = Auxiliary propulsion system sensor data collection and signal conditioning
E4.F6.G6 = Auxiliary propulsion system command auxiliary processing and fluid/mechanical control
E4.F6.G7 = Differential auxiliary propulsion throttling for actuating vehicle stability and control
E4.F6.G8 = Auxiliary propulsion flow-path-induced power takeoff (e.g., ullage or shaft-powered takeoff)
E4.F6.G9 = Hardware contamination flush/purging for auxiliary propulsion start/restart

E4.F7 = Supply onboard auxiliary reaction mass
E4.F7.G1 = Supply auxiliary reaction mass
E4.F7.G2 = Supply auxiliary reaction mass bias/margin

E4.F8 = Supply fluid/gas medium/media(s) for auxiliary propulsion purge, pressurization, and flow path control
E4.F8.G1 = Supply medium/media(s) for purging
E4.F8.G2 = Supply medium/media(s) for auxiliary propulsion pressurization
E4.F8.G3 = Supply medium/media(s) for auxiliary propulsion ullage
E4.F8.G4 = Supply fluid/gas medium/media(s) for propulsion control

4.3.3.5 Level F – Electrical Power Generation, Control, and Distribution Subsystem/Subfunction Codes

For the ALTIA effort, the F-SBS codes for generic electrical power management subsystems are defined as follows:

E5.F1 = Energy/power source (for centralized electric power to more than one function)
E5.F1.G1 = Toxic-fueled auxiliary power generation (e.g., hydrazine-supplied)
E5.F1.G2 = Nontoxic-fueled auxiliary power generation (e.g., kerosene-supplied)
E5.F1.G3 = Hi-press blow down auxiliary power generation (e.g., GN2 bottles)
E5.F1.G4 = Hot-gas blow down auxiliary power generation (e.g., solid prop gen)
E5.F1.G5 = Fuel supplied (fuel cell type) power generation
E5.F1.G6 = Electrochemical energy storage (provide battery-type primary vehicle electrical power)

E5.F2 = Electric power conversion (energy source supplied from another subsystem function)
E5.F2.G1 = Gas-driven rotating machine power conversion (e.g., ullage gas-driven turbo-machinery)
E5.F2.G2 = Mechanically driven rotating machine power conversion (e.g., main engine shaft takeoff)

E5.F3 = Electrical power distribution
E5.F3.G1 = Power control and switching
E5.F3.G2 = Distribute electrical power

E5.F4 = Supply consumable medium/media(s) for electrical power generation
E5.F4.G1 = Supply replenishable fluid/gas medium/media(s) as replenished power reactants
E5.F4.G2 = Supply replenishable bias/margin for power reactant medium/media(s)

E5.F5 = Supply dedicated medium/media(s) for power reactant purge, pressurization, and cooling
E5.F5.G1 = Supply medium/media(s) for power reactant purging
E5.F5.G2 = Supply medium/media(s) for power reactant pressurization
E5.F5.G3 = Supply medium/media(s) for electric power generation cooling

4.3.3.6 Level F – Mechanical Power Generation, Control, and Distribution Subsystem/Subfunction Codes

For the ALTIA effort, the F-SBS codes for generic mechanical power management subsystems are defined as follows:

E6.F1 = Energy source (for centralized fluid/gas powered mechanical controls to more than one subsystem)
E6.F1.G1 = Dedicated power generation w/toxic fuel supply (e.g., N2H4 supply)
E6.F1.G2 = Dedicated power generation w/nontoxic fuel supply (e.g., kerosene or propane supply)
E6.F1.G3 = Hi-press gas blow down supply (e.g., h.p. GN2 distribution)
E6.F1.G4 = Hot-gas blow down supply (e.g., solid propellant gas generation)
E6.F1.G5 = Dedicated electrochemical supply for driving pneumo-, hydraulic distribution

E6.F2 = Mechanical fluid power conversion

E6.F2.G1 = Pneumatic pressure supply (for centralized pneumatic controls to more than one function)
E6.F2.G2 = Hydraulic pressure power supply (for centralized hydraulic controls to more than one function)

E6.F3 = Fluid-mechanical power distribution
E6.F3.G1 = Pressurized pneumatic control distribution and regulation
E6.F3.G2 = Pressurized hydraulic fluid distribution and regulation
E6.F4 = Supply energy source fluid/gas medium/media(s) for mechanical power generation
E6.F4.G1 = Supply energy source reaction mass
E6.F4.G2 = Supply energy source reaction mass bias/margin

E6.F5 = Supply working fluid/gas medium/media(s) for mechanical power generation
E6.F5.G1 = Supply working fluid medium/media for distributed hydraulic power generation
E6.F5.G2 = Supply gas medium/media(s) for distributed pneumatic power generation

E6.F6 = Supply fluid/gas medium/media(s) for mechanical power generation purge, pressurization, and cooling
E6.F6.G1 = Supply medium/media(s) for mechanical power generation purging
E6.F6.G2 = Supply medium/media(s) for mechanical power generation pressurization
E6.F6.G3 = Supply distributed lubrication medium/media(s) for mechanical power generation
E6.F6.G4 = Supply cooling medium/media(s) for mechanical power generation

4.3.3.7 Level F – Thermal Protection Subsystem/Subfunction Codes

For the ALTIA effort, the F-SBS codes for generic thermal protection subsystems are defined as follows:

E7.F1 = Passive thermal protection
E7.F1.G1 = Ablative protection
E7.F1.G2 = Foam-applied ablative protection

E7.F2 = Permanent thermal protection
E7.F2.G1 = Materially ensure integrity of “hot structure”
E7.F2.G2 = Externally protect “cold structure” (i.e., insulate through attached materials)
E7.F2.G3 = Actively cool the structure

4.3.3.8 Level F – Environmental Control Subsystem/Subfunction Codes

For the ALTIA effort, the F-SBS codes for generic environmental control subsystems are defined as follows:

E8.F1 = Heat collection and radiation
E8.F1.G1 = Heat collection
E8.F1.G2 = Radiation

E8.F2 = Thermal transport and distribution
E8.F2.G1 = Passive two-phase heat transfer (e.g. heat pipe transport)
E8.F2.G2 = Active fluid transfer (e.g., NH3/Freon/alcohol, water)
E8.F2.G3 = Heat exchange
E8.F2.G4 = Electric source heating

E8.F3 = Vehicle environmental pressurization control
E8.F3.G1 = Vehicle structure pressurization supply (e.g., purge sources)
E8.F3.G2 = Vehicle structure pressurization distribution/regulation (e.g., purge ducts, interconnecting equipment)
E8.F3.G3 = Vehicle structure venting
E8.F3.G4 = Dedicated internal acoustic energy

E8.F4 = Supply environmental control fluid/gas transfer medium/media(s)
E8.F4.G1 = Supply coolant medium/media(s) for environmental control
E8.F4.G2 = Supply inert gas medium/media(s) for environmental control
E8.F4.G3 = Supply other fluid/gas medium/media(s) for environmental control

4.3.3.9 Level F – Command and Data Management Subsystem/Subfunction Codes

For the ALTIA effort, the F-SBS codes for generic command and data management subsystems are defined as follows:

E9.F1 = Vehicle systems command and data distribution/signal conditioning
E9.F1.G1 = Vehicle systems data integration and multiplexing
E9.F1.G2 = Vehicle systems signal conversion, amplification and distribution

E9.F2 = Vehicle systems command and data processing
E9.F2.G1 = Flight-critical command and data processing
E9.F2.G2 = Noncritical instrumentation and systems housekeeping processing

E9.F3 = Vehicle information storage and retrieval
E9.F3.G1 = Flight critical data storage and retrieval
E9.F3.G2 = Noncritical instrumentation and systems housekeeping data storage and retrieval

E9.F4 = Offboard information receiving, formatting and transmission
E9.F4.G1 = Flight-critical information receiving, formatting and transmission
E9.F4.G2 = Noncritical instrumentation/system housekeeping data receiving, formatting and transmission

4.3.3.10 Level F – Communications and Tracking Subsystem/Subfunction Codes

For the ALTIA effort, the F-SBS codes for generic communications and tracking subsystems are defined as follows:

E10.F1 = Vehicle long-range voice and data connectivity
E10.F1.G1 = Long-range voice and data radiofrequency (RF) radiation/signal collection
E10.F1.G2 = Long-range voice and data radiofrequency (RF) signal processing and conversion

E10.F2 = Vehicle short-range (EVA) voice and data connectivity
E10.F2.G1 = Short-range (EVA) voice and data RF radiation/signal collection
E10.F2.G2 = Short-range (EVA) voice and data RF signal processing and conversion

E10.F3 = Vehicle positioning and ground tracking connectivity
E10.F3.G1 = Vehicle positioning and ground tracking RF radiation/signal collection
E10.F3.G2 = Vehicle positioning and ground tracking RF signal processing and conversion

E10.F4 = Vehicle in-space rendezvous tracking and ranging connectivity
E10.F4.G1 = Vehicle in-space rendezvous tracking and ranging RF radiation/signal collection
E10.F4.G2 = Vehicle in-space rendezvous tracking and ranging RF signal processing and conversion

4.3.3.11 Level F – Guidance and Navigation (G&N) Subsystem/Subfunction Codes

For the ALTIA effort, the F-SBS codes for generic guidance and navigation (G&N) subsystems are defined as follows:

E11.F1 = Onboard state determination
E11.F1.G1 = Air data sensing and conversion
E11.F1.G2 = Onboard inertial vehicle state determination
E11.F1.G3 = Vehicle flex-mode sensing (body-mounted local rate and acceleration)
E11.F1.G4 = Celestial/star tracking and navigation

E11.F2 = Offboard state determination
E11.F2.G1 = Ground-communicated state determination (e.g., MLS)
E11.F2.G2 = Space-based state determination (e.g., global positioning satellite network)

4.3.3.12 Level F – Flight Termination and Abort Mode Switching Subsystem/Subfunction Codes

For the ALTIA effort, the F-SBS codes for generic guidance and navigation (G&N) subsystems are defined as follows:

E12.F1 = Dedicated flight termination and abort mode switching
E12.F1.G1 = Dedicated manual flight termination sensing and commanding
E12.F1.G2 = Manual flight crew abort mode switching control and switching

E12.F2 = Destructive flight termination
E12.F2.G1 = Ordnance destruct

4.3.3.13 Level F – Flight Crew Interfacing Subsystem/Subfunction Codes

For the ALTIA effort, the F-SBS codes for generic flight crew interfacing subsystems are defined as follows:

E13.F1 = Manual control of flight
E13.F1.G1 = Manual vehicle flight control
E13.F1.G2 = Crew display

E13.F2 = Manual systems management
E13.F2.G1 = Manual system control, mode changing, switching and configuration
E13.F2.G2 = Caution and warning interaction
E13.F2.G3 = Internal lighting control

4.3.3.14 Level F – External Lighting Subsystem/Subfunction Codes

For the ALTIA effort, the F-SBS codes for generic external lighting subsystems are defined as follows:

E14.F1 = In-flight lighting (ascent descent/landing)
E14.F1.G1 = Vehicle landing, position, and beacon lighting

E14.F2 = In-space lighting
E14.F2.G1 = Area flood lighting
E14.F2.G2 = Localized external lighting

4.3.3.15 Level F – Stage/Element Separation Subsystem/Subfunction Codes

For the ALTIA effort, the F-SBS codes for generic stage/element separation subsystems are defined as follows:

E15.F1 = Separating without explosives
E15.F1.G1 = Routine mechanical stage/element separation/jettison (e.g., spring sets)
E15.F1.G2 = Contingency mechanical abort mode separation/jettison (e.g., spring sets)

E15.F2 = Separating with explosives
E15.F2.G1 = Routine stage/element separation/jettison motors
E15.F2.G2 = Contingency abort mode ordnance separation/jettison

4.3.3.16 Level F – Launch/Takeoff and Landing Support Subsystem/Subfunction Codes

For the ALTIA effort, the F-SBS codes for generic launch/takeoff and landing support subsystems are defined as follows:

E16.F1 = Air launch mode
E16.F1.G1 = External stores – drop interfacing
E16.F1.G2 = External piggyback – top-mounted/dorsal interfacing
E16.F1.G3 = Internalized store interfacing (e.g., bomb bay, rear cargo doors)

E16.F2 = Ground launch assist
E16.F2.G1 = Passive ground launch rail interfacing (flight half function)
E16.F2.G2 = Active mag-lev thrust platform interfacing (flight half function)

4.3.3.17 Level F – Personnel Accommodation Subsystem/Subfunction Codes

For the ALTIA effort, the F-SBS codes for generic personnel accommodation subsystems are defined as follows:

E17.F1 = Internal cabin structural accommodations
E17.F1.G1 = Pressurized cabin enclosure structural function
E17.F1.G2 = Cabin ingress/egress hatchway provisioning
E17.F1.G3 = Window outfitting/viewing structural provisioning
E17.F1.G4 = Internalized structure for pressure equalization (i.e., airlock provisioning)

E17.F2 = Life support outfitting of vehicle cabin
E17.F2.G1 = Habitation pressurization supply
E17.F2.G2 = Habitation pressurization distribution and supply
E17.F2.G3 = Habitation venting
E17.F2.G4 = Habitation heating supply and exchange
E17.F2.G5 = Habitation cooling supply and exchange
E17.F2.G6 = Habitation heat distribution and regulation
E17.F2.G7 = Breathing air O2 storage and supply
E17.F2.G8 = Breathing air N2 storage and supply
E17.F2.G9 = Breathing air microbial and contaminant control/filtration
E17.F2.G10 = Breathing air humidity control, distribution and regulation
E17.F2.G11 = Passive radiation insulation/shielding
E17.F2.G12 = Active radiation shielding

E17.F3 = Intravehicular crew/passenger provisioning
E17.F3.G1 = Seating and restraining
E17.F3.G2 = Protection and emergency provisioning
E17.F3.G3 = Personal storage
E17.F3.G4 = Food preparation
E17.F3.G5 = Potable water management
E17.F3.G6 = Sleep accommodations
E17.F3.G7 = Medical provisioning
E17.F3.G8 = Fitness and recreation
E17.F3.G9 = Hygiene accommodation
E17.F3.G10 = Trash management
E17.F3.G11 = Biological waste management

E17.F4 = Extravehicular activity (EVA) provisioning
E17.F4.G1 = Suit storage and support
E17.F4.G2 = Suit storage and support
E17.F4.G3 = Extravehicular crew propulsion and maneuvering
E17.F4.G4 = Extravehicular equipment support and tooling

E17.F4.G5 = Other extravehicular activity (EVA) functions

E17.F5 = Supply fluid/gas medium/media(s) for life support functions
E17.F5.G1 = Supply breathing air constituents
E17.F5.G2 = Supply fluid medium/media(s) for hydration (e.g., provide potable water)
E17.F5.G3 = Supply other life support fluid/gas medium/media(s) (e.g., biocide treatment supply)

4.3.3.18 Level F – Payload Accommodation (Vehicle Internalized) Subsystem/Subfunction Codes

For the ALTIA effort, the F-SBS codes for generic payload accommodation (vehicle internalized) subsystems are defined as follows:

E18.F1 = Pressurized payload accommodation
E18.F1.G1 = Pressurized payload structural support and enclosure (e.g., locker/rack accommodations)
E18.F1.G2 = Pressurized payload access (i.e., door/panel provisioning)

E18.F2 = Unpressurized payload accommodation
E18.F2.G1 = Unpressurized payload structural support and enclosure (e.g., unpressurized payload bay or “trunk”)
E18.F2.G2 = Unpressurized payload access (i.e., door/panel provisioning)

4.4 Spaceflight Ground/Surface Segment Functional Codes

This section provides the functional coding schema for the ground (or lunar/planetary surface) systems segment of the spaceflight architecture. The intent is to provide a catalog of functions for ground items that may be potentially required, depending on the nature and complexity of a flight system architecture specified to equivalent levels of functional detail. Note: For the purposes of these functional codes, the term “ground” can be broadly applied to include lunar/planetary surface-based systems.

A conceptual model of the ground functions of spaceflight ground systems are diagrammed in Figure 25.

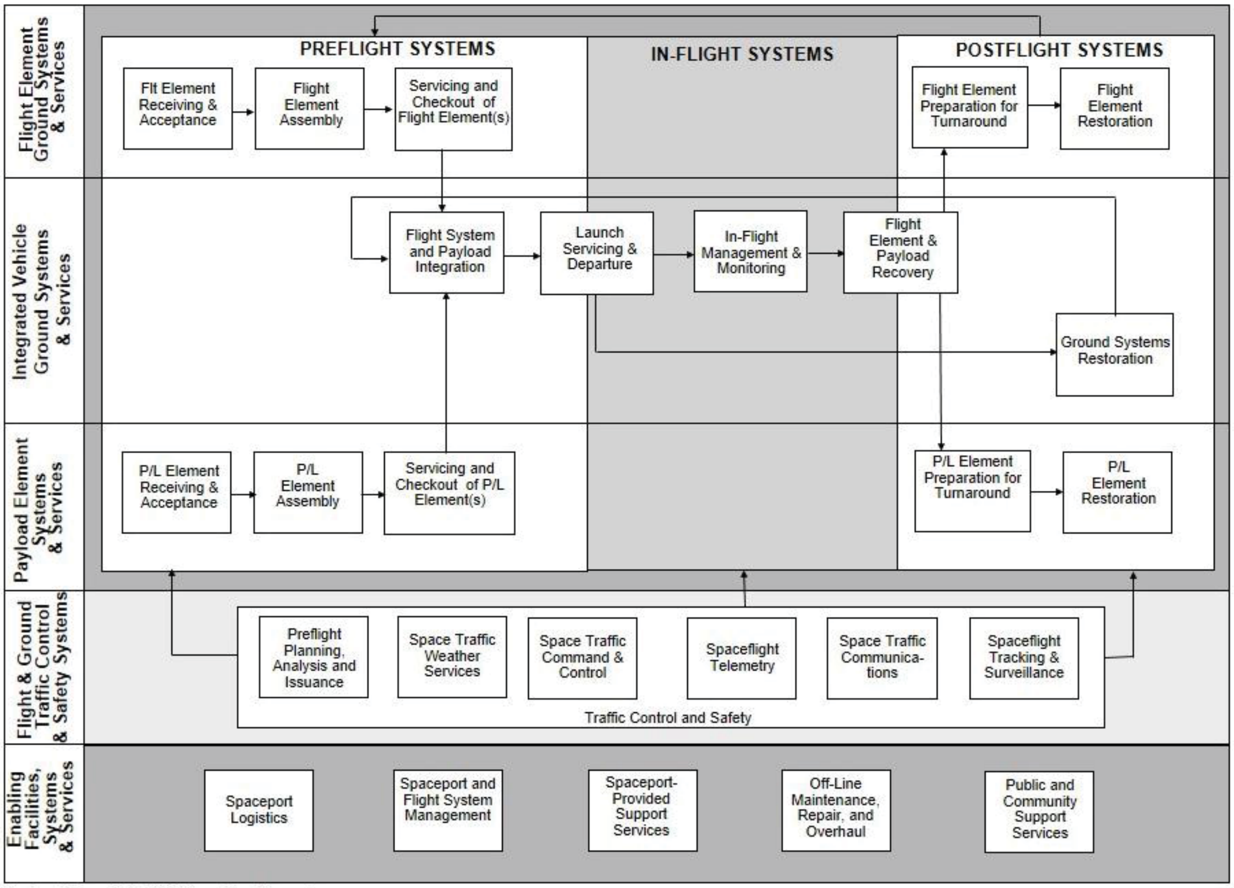
Generally, the ground systems that are directly associated with processing of the flight systems defined in the Flight Segment (Section 4.2) can be categorized according to the three areas shown left to right in the diagram. These ground systems are associated with preflight and postflight operations, along with those used for in-flight monitoring, tracking, and range control.

In addition, each of these types of ground systems tends to be arranged at a launch site by three or four other functional categories:

- Stand-alone flight element operations

- Integrated space vehicle operations (where the flight elements and payload come together as a space vehicle)

- Stand-alone payload element operations



Derived from ASTWG Baseline Report

Figure 25. Generic Model of Spaceflight Ground Functional Flow

Also to be considered are systems associated with controlling vehicle movements: ground vehicles on roadways; waterborne vessels such as barges; aircraft; and, of course, spaceflight traffic and their ascent and entry corridors. As shown by the arrows in the diagram, these systems have a direct relation to the preflight, postflight, and inflight systems.

In support of all these systems (depending on the scale of the operations at the spaceflight complex), are separate facilities, systems, networks, and services that enable the foregoing ground systems to operate effectively and efficiently. These may include the following: ground logistics, and perhaps some flight systems logistics; administrative management; internally provided utility provisions and services (air products, nitrogen, and other distributed and consumed commodities, as well as specialized communications services). It also may include off-line fabrication, repair, and analysis capabilities.

Finally, connectivity to the surrounding public environment, such as various modes of ground, water, and air transport may be provided; as well as provisions for connecting to externally provided utilities, for example, electrical power, commercial communications, and public water and sewer connections.

By understanding the innovative ways in which they can be engineered, these ground functions can evolve from today's launch complexes to the creation of productive space transportation ports of call. The following is a preliminary list of ground functions to consider when building spaceflight architectures, and which is planned to be reviewed and updated in 2015 by KSC's Systems Integration Branch.

4.4.1 Level D – Spaceflight Ground/Surface System Element Functional Codes

For the ALTIA effort, the Level D F-SBS codes for generic spaceflight ground systems elements are as follows:

D1 = Flight element preflight processing
D2 = Flight element off-line maintenance, repair and overhaul
D3 = Space vehicle assembly and integration
D4 = Departure/launch
D5 = Vehicle-to-departure point adaptation (servicing and access)
D6 = Vehicle recovery
D7 = Horizontal space vehicle takeoff/land
D8 = Propulsive vertical landing vehicle recovery
D9 = Parachute recovery and retrieval
D10 = Spacecraft element preflight processing
D11 = Spacecraft element refurbishment and overhaul
D12 = Space payload/cargo packaging and handling
D13 = Dedicated flight and ground system command, control, and monitoring
D14 = In-flight vehicle safety control and/or monitoring

4.4.2 Level E – Spaceflight Ground/Surface Element Subsystem Discipline Codes

For the ALTIA effort, the Level E F-SBS codes for generic spaceflight ground element subsystem disciplines are as follows:

E1 = Site and primary ground structural functions
E2 = Propellant and fluid management
E3 = Gas ground supply and environmental control
E4 = Ground mechanical functions
E5 = Special-purpose ground electrical power management
E6 = Ground command and control
E7 = Ground communications
E8 = Concept-unique infrastructure functions
E9 = Spaceflight traffic control (space range functions)

4.4.3 Level F and G – Ground/Surface Subsystem Function/Subfunction Codes

For the ALTIA effort, the Level F and G F-SBS codes for generic ground element subsystems are defined in this section and organized by the appropriate Level E ground discipline.

4.4.3.1 Site and Primary Ground/Surface Structural Subsystem Discipline/Subfunction Codes

For the ALTIA effort, the F-SBS codes for generic site and primary ground structural functions are defined as follows:

E1.F1 = Site grounds, maintenance, and control
E1.F1.G1 = Site security, safety, environmental monitoring
E1.F1.G2 = Site lighting
E1.F1.G3 = Site drainage, wastewater and disposal technologies
E1.F1.G4 = Site transport connectivity
E1.F1.G5 = Hazardous commodity local storage and bunkering
E1.F1.G6 = Site electric power provisions and service points
E1.F1.G7 = Site telecommunications provisions and service points

E1.F2 = Ground station primary structural functions
E1.F2.G1 = Enclosed processing w/limited personnel housing (hangar-like)
E1.F2.G2 = Enclosed processing w/local full-service housing
E1.F2.G3 = Temporary processing and housing
E1.F2.G4 = Fixed with simple personnel access
E1.F2.G5 = Fixed with mechanized personnel access (e.g., with elevators)
E1.F2.G6 = Movable with simple personnel access
E1.F2.G7 = Movable with mechanized personnel access (e.g., with elevators)

4.4.3.2 Site and Primary Propellant and Fluid Management Discipline Subsystem/Subfunction Codes

For the ALTIA effort, the F-SBS codes for generic primary propellant and fluid management functions are defined as follows:

E2.F1 = Cryogenic fuel management
E2.F1.G1 = Liquid hydrogen (LH2) ground storage
E2.F1.G2 = Liquid hydrogen (LH2) ground distribution, transfer, and conditioning
E2.F1.G3 = Liquid hydrogen (LH2) ground recovery and boiloff
E2.F1.G4 = Liquid methane/natural gas (CH4/LNG) ground storage
E2.F1.G5 = Liquid methane/natural gas (CH4/LNG) ground distribution, transfer and conditioning
E2.F1.G6 = Liquid methane/natural gas (CH4/LNG) CH4/LNG recovery and boiloff

E2.F2 = Cryogenic oxidizer management
E2.F2.G1 = Liquid oxygen (LO2) ground storage
E2.F2.G2 = Liquid oxygen (LO2) ground distribution, transfer, and conditioning

E2.F2.G3 = Liquid oxygen (LO2) ground recovery and boiloff

E2.F3 = Specialized supercooled cryogenic propellant management
E2.F3.G1 = Liquid hydrogen (LH2) conditioning densification and heat exchange
E2.F3.G2 = Liquid oxygen (LO2) conditioning densification and heat exchange
E2.F3.G3 = Cryogenic conditioning densification and heat exchange of other commodities

E2.F4 = Kerosene (RP-1) propellant management
E2.F4.G1 = Kerosene (RP-1) ground storage
E2.F4.G2 = Kerosene (RP-1) ground distribution, transfer, and conditioning
E2.F4.G3 = Kerosene (RP-1) ground recovery and disposal

E2.F5 = Specialized fuel management
E2.F5.G1 = Unsymmetrical dimethylhydrazine (UDMH) ground storage
E2.F5.G2 = Unsymmetrical dimethylhydrazine (UDMH) distribution, transfer, and conditioning
E2.F5.G3 = Unsymmetrical dimethylhydrazine (UDMH) ground recovery and disposal
E2.F5.G4 = Aerozine-50 ground storage
E2.F5.G5 = Aerozine-50 ground distribution, transfer, and conditioning
E2.F5.G6 = Aerozine-50 ground recovery and disposal
E2.F5.G7 = Monomethylhydrazine (MMH) ground storage
E2.F5.G8 = Monomethylhydrazine (MMH) ground distribution, transfer, and conditioning
E2.F5.G9 = Monomethylhydrazine (MMH) recovery
E2.F5.G10 = UH25 (25% hydrated hydrazine) ground storage
E2.F5.G11 = UH25 (25% hydrated hydrazine) ground distribution, transfer, and conditioning
E2.F5.G12 = UH25 (25% hydrated hydrazine) ground recovery and disposal
E2.F5.G13 = Ethanol ground storage
E2.F5.G14 = Ethanol ground distribution, transfer, and conditioning
E2.F5.G15 = Ethanol ground recovery and disposal
E2.F5.G16 = Syntin propellant ground storage
E2.F5.G17 = Syntin ground distribution, transfer, and conditioning
E2.F5.G18 = Syntin ground recovery and disposal
E2.F5.G19 = Other specialized fuel ground storage
E2.F5.G20 = Other specialized fuel ground distribution, transfer, and conditioning
E2.F5.G21 = Other specialized fuel recovery and disposal

E2.F6 = Specialized oxidizer management
E2.F6.G1 = Nitrogen tetroxide (N2O4) ground storage
E2.F6.G2 = Nitrogen tetroxide (N2O4) ground distribution, transfer, and conditioning
E2.F6.G3 = Nitrogen tetroxide (N2O4) ground recovery and disposal
E2.F6.G4 = Nitric acid ground storage
E2.F6.G5 = Nitric acid ground distribution, transfer, and conditioning
E2.F6.G6 = Nitric acid ground recovery and disposal

E2.F6.G7 = Peroxide/HTP ground storage
E2.F6.G8 = Peroxide/HTP ground distribution, transfer, and conditioning
E2.F6.G8 = Peroxide/HTP ground recovery and disposal
E2.F6.G9 = Other specialized oxidizer ground storage
E2.F6.G10 = Other specialized oxidizer ground distribution, transfer, and conditioning
E2.F6.G11 = Other specialized oxidizer ground recovery and disposal

E2.F7 = Power reactant fluid management
E2.F7.G1 = Fuel power reactant ground storage
E2.F7.G2 = Fuel power reactant ground distribution, transfer, and conditioning
E2.F7.G3 = Fuel power reactant ground recovery/boiloff
E2.F7.G4 = Oxidizer power reactant ground storage
E2.F7.G5 = Oxidizer power reactant ground distribution, transfer, and conditioning
E2.F7.G6 = Oxidizer power reactant ground recovery/boiloff

E2.F8 = Ground-supplied cooling/active thermal control fluid management
Ammonia (NH3) ground supply
Other ground-supplied cooling

E2.F9 = Ground management of flight hydraulics
E2.F9.G1 = Fixed, hi flow/capacity ground hydraulic supply
E2.F9.G2 = Fixed, normal flow/capacity ground hydraulic supply
E2.F9.G3 = Portable, normal flow/capacity ground hydraulic supply

E2.F10 = Management of launch accessory hydraulics
E2.F10.G1 = Fixed, hi flow/capacity ground hydraulic supply
E2.F10.G2 = Fixed, normal flow/capacity ground hydraulic supply
E2.F10.G3 = Portable, normal flow/capacity ground hydraulic supply

E2.F11 = Ancillary operational fluid functions
E2.F11.G1 = Liquid nitrogen supply, distribution, and disposal
E2.F11.G2 = Water (Grade A or B) supply, distribution, and disposal
E2.F11.G3 = Potable water supply, distribution, and disposal
E2.F11.G4 = Custom EVA suit cooling water supply, distribution, and disposal
E2.F11.G5 = Specialized heat transport water supply, distribution, and disposal
E2.F11.G6 = Argon supply, distribution, and disposal
E2.F11.G7 = Lube oil supply, distribution, and disposal
E2.F11.G8 = Carbon dioxide supply, distribution, and disposal
E2.F11.G9 = Biocide flush fluid supply, distribution, and disposal
E2.F11.G10 = Avionics fire-extinguishing fluid supply, distribution, and disposal
E2.F11.G11 = PGME/water azeotrope supply, distribution, and disposal

4.4.3.3 Ground Gas Supply and Environmental Control Discipline Subsystem/Subfunction Codes

For the ALTIA effort, the F-SBS codes for generic gas ground supply and environmental control functions are defined as follows:

E3.F1 = Supply air from the ground at acceptable temperature, humidity, flow rate, and quality/cleanliness for environmental control
E3.F1.G1 = Process/pump ambient air
E3.F1.G2 = Store and supply water vapor mixtures and low-pressure GN2
E3.F1.G3 = Distribute and control air flow to end use flight and ground system volumes

E3.F2 = Supply gaseous helium (GHe) from the ground for onboard safety purges and pressurization
E3.F2.G1 = Store, supply, condition, and filter gaseous helium (GHe)
E3.F2.G2 = Distribute and control gaseous helium (GHe) flow to flight and ground systems

E3.F3 = Supply gaseous nitrogen (GN2) from the ground for facility purges and onboard safety purges and pressurization
E3.F3.G1 = Store, supply, condition, and filter gaseous nitrogen (GN2)
E3.F3.G2 = Distribute and control gaseous nitrogen (GN2) flow

E3.F4 = Supply gaseous oxygen (GO2) from the ground to service onboard containers/vessels
E3.F4.G1 = Store, supply, condition, and filter gaseous oxygen (GO2)
E3.F4.G2 = Distribute and control gaseous oxygen (GO2) flow

E3.F5 = Supply breathing air (BAIR) from the ground to facilities and spacecraft
E3.F5.G1 = Store, supply, condition, and filter breathing air (BAIR)
E3.F5.G2 = Distribute and control breathing air (BAIR) flow

E3.F6 = Supply gaseous nitrogen (GN2) and gaseous helium (GHe) from the ground to propellant and vehicle propulsion systems for pneumatic control and emergency safing
E3.F6.G1 = Store, condition, and filter nitrogen (GN2) and helium (GHe) ground pneumatic gas supply
E3.F6.G2 = Distribute and control nitrogen (GN2) and helium (GHe) ground pneumatic gas flow

4.4.3.4 Ground Mechanical Subsystem Discipline/Subfunction Codes

For the ALTIA effort, the F-SBS codes for ground mechanical subsystem disciplines are defined as follows:

E4.F1 = Personnel and flight crew access
E4.F1.G1 = Fixed ground personnel mold line access to flight system
E4.F1.G2 = Movable ground personnel mold line access to flight system

E4.F1.G3 = Temporary/mobile ground personnel mold line access to flight system
E4.F1.G4 = Fixed ground personnel access (clean room level)
E4.F1.G5 = Movable ground personnel access (clean room level)
E4.F1.G6 = Temporary/mobile ground personnel access (clean room level)
E4.F1.G7 = Internal vehicle access

E4.F2 = Service connectivity (e.g., mechanical umbilical functions)
E4.F2.G1 = Structural/mechanical support
E4.F2.G2 = Umbilical actuation
E4.F2.G3 = Umbilical disconnect triggering
E4.F2.G4 = Umbilical fluid line connectivity
E4.F2.G5 = Umbilical electrical power connectivity
E4.F2.G6 = Umbilical instrumentation connectivity
E4.F2.G7 = Environmental/thermal protection

E4.F3 = Exhaust gas management
E4.F3.G1 Flame deflection/diffusion

E4.F4 = Vehicle stabilization and support
E4.F4.G1 = Stabilize vehicle rotations from vertical (sway)
E4.F4.G2 = Support vehicle gravity loads
E4.F4.G3 = Support vehicle start-up liftoff loads

E4.F5 = Vehicle handling
E4.F5.G1 = Translational lifting/lowering
E4.F5.G2 = Rotating around vertical
E4.F5.G3 = Tilting from vertical
E4.F5.G4 = Positioning, alignment and registration (relative/fixed orientations)

E4.F6 = Specialized ground transport
E4.F6.G1 = Two-dimensional steered transport
E4.F6.G2 = One-dimensional transport (e.g., rail transport)
E4.F6.G3 = Transport propulsion (of hauled item)

E4.F7 = Vehicle ground attachment and adaptation
E4.F7.G1 = Vehicle vertical launch support/attachment
E4.F7.G2 = Exhaust path compatibility – i.e., exhaust hole location(s)

E4.F8 = Ignition overpressure and sound suppression
E4.F8.G1 = Sound suppression deluging
E4.F8.G2 = Dedicated ignition overpressure control

4.4.3.5 Special-Purpose Ground Electrical Power Management/Subfunction Codes

For the ALTIA effort, the F-SBS codes for ground special power functions/subfunctions are defined as follows:

E5.F1 = Uninterruptable supply of electrical power
E5.F1.G1 = Power integration with utility supply
E5.F1.G2 = Regulated and protected supply to facility and ground support equipment
E5.F1.G3 = Regulated and protected supply to flight elements

E5.F2 = Supply of special-purpose DC electrical power
E5.F2.G1 = Supply of special DC electrical power to facility and ground support equipment
E5.F2.G2 = Supply of special DC electrical power to flight elements

E5.F3 = Supply of special-purpose AC electrical power
E5.F3.G1 = Supply of special AC electrical power to facility and ground support equipment
E5.F3.G2 = Supply of special AC electrical power to flight elements

E5.F4 = Lightning protection
E5.F4.G1 = Field mill detection
E5.F4.G2 = Lightning strike absorption
E5.F4.G3 = Lightning strike dissipation and/or energy capture

4.4.3.6 Ground Command and Control Functions/Subfunction Codes

For the ALTIA effort, the F-SBS codes for ground command and control functions/subfunctions are defined as follows:

E6.F1 = Provide ground commands to flight and ground functions (i.e., “commanding” capability)
E6.F1.G1 = Provide time-critical ground safing commands to high energy flight and ground functions
E6.F1.G2 = Provide sequential and system prerequisite logic in command issuance

E6.F2 = Provide information from flight and ground systems to ground operators (i.e., “monitoring” capability)
E6.F2.G1 = Provide operator visibility of system performance and status
E6.F2.G2 = Provide operator notifications of safety conditions (alarms, cautions, warnings)

E6.F3 = Initiate and/or execute tasks and procedures remote from equipment for safe, efficient, and automatic servicing and checkout of flight and ground systems (i.e., “automation” capability).
E6.F3.G1 = Provide remote and/or local assembly tasks
E6.F3.G2 = Provide remote and/or local systems servicing tasks

E6.F3.G3 = Provide remote and/or local checkout/inspection of system functional integrity

E6.F2 = Provide information from flight and ground systems to ground operators (i.e., “monitoring” capability).
E6.F2.G1 = Provide operator visibility of system performance and status
E6.F2.G2 = Provide operator notifications of safety conditions (alarms, cautions, warnings)

E6.F3 = Initiate and/or execute tasks and procedures remote from equipment for safe, efficient, and automatic servicing and checkout of flight and ground systems (i.e., “automation” capability).
E6.F3.G1 = Provide remote and/or local assembly tasks
E6.F3.G2 = Provide remote and/or local systems servicing tasks
E6.F3.G3 = Provide remote and/or local checkout/inspection of system functional integrity
E6.F3.G4 = Provide remote execution and monitoring of launch/departure and flight
E6.F3.G5 = Provide remote and/or local control and monitoring of recovery and retrieval
E6.F3.G6 = Provide remote and/or local control and monitoring of recovery and retrieval
E3.F3.G7 = Provide remote and/or local diagnostic sequencing from troubleshooting, through verification and closeout of functional restoration

4.4.3.7 Ground Communications Functions/Subfunction Codes

For the ALTIA effort, the F-SBS codes for ground communications functions/subfunctions are defined as follows:

E7.F1 = Transmission between elements of the global/universal spaceflight architecture
E7.F1.G1 = Provide hardline transmission capability
E7.F1.G2 = Provide wideband wireless transmission capability (local range and other ground- and space-based network elements)
E7.F2 = Information technology exchange (voice, data, video, inter-network exchange)
E7.F2.G1 = Provide publicly accessible IT exchange
E7.F2.G2 = Provide secure administrative IT exchange
E7.F2.G3 = Provide secure operational voice, imaging, video and data exchange for spaceflight operations (preflight, flight, and postflight)
E7.F2.G4 = Provide local ground station personnel paging and area warning
E7.F2,G5 = Provide highly reliable, precise, and accurate master timing references for all ground stations for ground checkout, launch, and flight operations

4.4.3.8 Portable and Facility Spaceflight Ground Services/Subfunction Codes

For the ALTIA effort, the F-SBS codes for infrastructure functions/subfunctions that are unique to a concept (and not infrastructure functions that are standardly available to any concept) are defined as follows:

E8.F1 = Special ground-station-supplied gas services
E8.F1.G1 = Facility-provided gaseous helium
E8.F1.G2 = Facility-provided gaseous nitrogen
E8.F1.G3 = Facility-provided breathing air (for personnel protection equipment)
E8.F1.G4 = Facility-provided compressed air supply

E8.F2 = Unique spaceflight facility emergency and safety services
E8.F2.G1 = Oxygen deficiency monitoring
E8.F2.G2 = Electronic facility security
E8.F2.G3 = Facility fire detection and suppression
E8.F2.G4 = Uninterruptible facility power
E8.F2.G5 = Facility grounding and lightning protection
E8.F2.G6 = Personnel safe havens within blast danger zones

E8.F3 = Other special spaceflight-facility-provided services
E8.F3.G1 = High performance heating, ventilating and air conditioning (if driven by special requirements)
E8.F3.G2 = Base/complex monitoring and mobilization (ground traffic control, wx, emergency and protective services)
E8.F3.G3 = Potable water supply
E8.F3.G4 = Facility- or ground-station-supplied personnel mobility services
E8.F3.G5 = Facility- or ground-station-supplied power
E8.F3.G6 = Wastewater collection, treatment, and disposal
E8.F3.G7 = Special illumination, lighting, and imaging (e.g., floodlighting, x-ray, ultrasound, other NDE services)
E8.F3.G8 = Unique pathways between ground stations
E8.F3.G9 = Precision alignment of large mobile structures within facilities

4.4.3.9 Spaceflight Traffic Control (Space Range) Functions/Subfunction Codes

For the ALTIA effort, the F-SBS codes for spaceflight traffic control functions/subfunctions (or “range” functions) are defined as follows:

E9.F1 = Spaceflight tracking and surveillance
E9.F1.G1 = Conduct surveillance – detect objects
E9.F1.G2 = Conduct surveillance – identify objects
E9.F1.G3 = Provide fix on object (time-space position information)

E9.F2 = Spaceflight telemetry
E9.F2.G1 = Acquire data from each vehicle in flight
E9.F2.G2 = Process data – de-commutate, scale, and reformat

E9.F3 = Space traffic communications
E9.F3.G1 = Distribute voice, video, data, and timing
E9.F3.G2 = Record and archive data
E9.F3.G3 = Spaceflight network administration and management

E9.F4 = Space traffic command and control
E9.F4.G1 = Monitor space traffic control asset health, status, and configuration
E9.F4.G2 = Monitor and mobilize space traffic control assets
E9.F4.G3 = Authorize and manage spaceflight vehicles in flight
E9.F4.G4 = Handover command and control of recovered spaceflight vehicles to ground crew

E9.F5 = Preflight planning, analysis, and issuance
E9.F5.G1 = Multi-flight resource allocations, sequencing, and manifesting
E9.F5.G2 = Route planning, scheduling and de-confliction
E9.F5.G3 = Outbound path analysis
E9.F5.G4 = Orbital path analysis
E9.F5.G5 = Inbound path analysis
E9.F5.G6 = Compilation of launch/departure clearance criteria
E9.F5.G7 = Space traffic control asset assignments and sequencing
E9.F5.G8 = Approval and distribution of flight planning products to systems operators

E9.F6 = Space traffic weather services
E9.F6.G1 = Forecasting of departure point, in-space, and return weather
E9.F6.G2 = Evaluation of weather criteria for flight authorizations and release
E9.F6.G3 = Induced environment propagation forecasting (toxic and/or radiation release, debris impact, and blast limit estimation)

4.5 Spaceflight System Breakdown Codes

The previous sections provided the *functional coding* schema to ensure that concepts are homogeneously defined across a full spectrum of needed capabilities, for both flight and ground functions. In this section a *system coding schema* defines each of the parts (i.e., all the nouns and objects of the architecture) of the architecture (or "system"), a hierarchical identification.

This System Breakdown Structure coding schema follows other standard breakdown schema using numeric terms separated by the "." character, and with a prefix identifying the architecture in the form:

USER-ASSIGNED DESCRIPTION	SBS ID
SYSTEM COMPONENT/ASSEMBLY NAME	1.2.3.4.5.6

where,

1 = User-assigned Architecture ID
2 = Sequential Concept Version/Class ID
3 = Architectural Segment ID (per Eq. 2, Section 2.3.2)
4 = Sequential Element ID
5 = Sequential Subsystem ID
6 = Sequential Component/Assembly ID

For a complete architectural system definition, the user supplies names for the architecture, the elements of the space vehicle, the ground stations and the launch and/or recovery locations, the production stations at the various manufacturing and assembly locations, and the business elements.

A System Definition Sheet then collects all the components/assemblies of each segment of the architecture to provide a complete flight and ground system definition that is defined to similar levels. This homogeneity of system definition allows for more comprehensive and therefore more accurate assessments of a conceptual architecture's cost, responsiveness, and reliability.

Through the System Definition Sheets, comparison metrics of the user's choice can then be attached to each component/assembly. For performance analysis, this may be mass, volume, or moment of inertia data, for instance. It may also be a comparison index for installed part complexity, complexity of interfaces, and nature of the ground interface (for example, toxic/ordnance/confined space interface to the ground), degree of reusability.

These measures can then be rolled up or otherwise determined at the subsystem level, the element level, the flight or ground segment level, and at the total architecture level, as appropriate, and provided to various performance, cost, and risk models.

5 OBSERVATIONS – CONCEPTUAL DESIGN FOR IMPROVED LIFE CYCLE OUTCOME

In pursuing the ALTIA tasks, the participants noted several principles and techniques that may be of interest to space architects of all sorts, but particularly to those pursuing advanced space concepts and technologies.

Principle 1: Missions are meant to be accomplished; architectures should endure. The process of designing the architecture for an enduring spaceflight capability has subtle differences that distinguish it from traditional space mission design; for example, a spacecraft mission, whether an unmanned probe to a planet, or a human spaceflight to earth orbit, has a defined beginning and end.

Sustainable space architecture implies a resulting capability that is at once effective and efficient on a repeated-use basis. Investments that mature advanced system concepts and new technologies may be required to grow from successful space missions to enduring space architectures.

Principle 2: Focus on the recurring outcome first—keep the end in mind for the benefit of the ultimate customer and the end user-operator. Too often, the outcome is determined by the resulting design and acquisition phases of the life cycle, leaving the recurring outcome to chance in favor of ease of up-front effort, and/or accomplishment of early-stage space missions or demonstrations only.

Maintaining a constant focus on the recurring phase of infrastructure support and operations helps the technical team *understand the need, the vision of improvement, and strive to meet the goals and objectives,* and it gives the stakeholders more confidence that the outcome will be realized than they normally experience.

Principle 3: Make the outcome do more with less, and avoid inadvertently settling for less with less. In considering the life cycle outcome, understand the productivity that results along with understanding the performance and cost. This means simultaneously understanding flight performance, production and supply rates, and cycle time—all in addition to understanding the recurring cost components.

Principle 4: Add it ALL up, and add it up early—by addressing early all the major functions that each element of the architectural design will ultimately have to perform. In this way the accumulation of system complexities, bottlenecks in productivity, implied infrastructure, and inherent risks—all will make themselves more visible to the architect and the technologist at a point in the process when corrective action is most practical.

This in turn allows the technical team to better reconfigure the architecture and to apply or invest in previously unconsidered technologies and technical approaches while there are still practical options for achieving enduring architectures.

With these basic principles in mind, a number of techniques are offered that may be found useful in the early concept formulation phase, and/or in technology portfolio creation.

Technique 1: Bring a small team of architects and technologies together from all life cycle segments—flight segment, ground segment, production and supply chain, as well as the business/market segments.

Technique 2: For the space systems architect, strive to minimize the number of uniquely designed elements and ground stations in the architecture to accomplish the objective. If one string of these elements can be made both affordable and productive to design, build, and operate, then multiple sets can be procured. On the other hand, if the accumulation of elements grows to a point where one string is unaffordable and not productive enough, then copying and pasting the elements of the architecture can lead to economic and/or political disaster!

Technique 3: For the space systems architect, strive to create elements of the architecture that accomplish the greatest amount of functionality in the minimum number of components and assemblies. This technique can have profound effects across the life cycle. It simplifies the number of separate designs and procurements, test and certification activities, the cumulative amount of production and operations equipment and infrastructure, and number of resulting production and operations tasks. In short, the total costs will add to less, and the system responsiveness—and thus productivity—is more likely to increase.

Technique 4: For the NASA technologist, strive to identify solutions for near-, mid-, and farther-term application of the solutions under investigation. This technique allows the architectural context to be pursued with reasonable expectations in the near term, while surfacing specific continuous improvement plans that include focused technology investments and system-level demonstrations.

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APPENDIX A. FOUR-STAGE ALL-SOLID SCOUT D1 LAUNCH VEHICLE DEFINITION SHEET

(created w/ACT prototype)

ACT_Id_No	Pedigree	Name	Description
6726	ST.LV	SCOUT D1 LAUNCH VEHICLE	
6727	ST.LV.A1	Algol IIIA First Stage	
6728	ST.LV.A1.ST	Structures	Scout Structures Item
6729	ST.LV.A1.ST.SP	Primary Structures	
6730	ST.LV.A1.ST.SP.FH	Algol IIIA Motor Case	Steel motor case interfaces to the transition A base, lower transition B structure, two tunnel mountings, and an ordnance interface with the motor propellant. (Source: NASA CR-165950/Pt. 1, p. 63.)
6878	ST.LV.A1.ST.SP.FH	Transition Section "A" Structure	Aluminum, semi-monocoque cylindrical shell. A bolted interface to the base of the rocket motor case; four fin structures; four tip fin/jet vane assembly attachments, and electronics mountings. (Source: NASA CR-165950/Pt. 1, p. 26.)
6879	ST.LV.A1.ST.SP.FH	Transition Section Lower "B" Structure	Provides primary load path between first and second stages of the Scout vehicle. Also, an interface to threaded diaphragm insert. Also, first stage mating structural mating interface. (Source: NASA CR-165950/Pt. 1, p. 26.)
6880	ST.LV.A1.ST.SP.39	Algol IIIA Motor Nozzle	Lightweight reinforced plastic nozzle. (Source: NASA CR-165950/Pt. 1, p. 63.)
6733	ST.LV.A1.ST.SS	Stabilizer Structure	
6734	ST.LV.A1.ST.SS.49	Algol IIIA Fixed Fins	Four fixed aerodynamic stabilizing fins structurally attached to the Transition "A" base structure. Also interfaces with tip fin/vane/torque tube mechanism. (Source: NASA CR-165950/Pt. 1, p. 26.)
6735	ST.LV.A1.ST.SR	Range Destruct	
6736	ST.LV.A1.ST.SR.RD	Algol IIIA Shaped Charges	There are two shaped charges. (Source: NASA CR-165950/Pt. 1, Fig. 57, p. 94.)
6749	ST.LV.A1.ST.SF	Fairing/Shrouds	
6750	ST.LV.A1.ST.SF.FX	Algol IIIA Wiring Tunnel Covers	Two opposing wiring tunnels with structural interfaces to the motor case. Also, encases two ordnance shaped charges. (Source: NASA CR-165950/Pt. 1, Fig. 5, p. 6.)
6737	ST.LV.A1.MP	Propulsion – Maneuvering	Scout Propulsion – Maneuvering Item
6738	ST.LV.A1.MP.MN	Main Propulsion	
6739	ST.LV.A1.MP.MN.SD	Algol IIIA Solid Motor Propellant	Propellant grain is tapered core, four-point star, internal burning configuration. Aluminized composite propellant with polybutadiene acrylic nitrile binder. (Source: NASA CR-165950/Pt. 1, p. 63.)

ACT_Id_No	Pedigree	Name	Description
6875	ST.LV.A1.MP.MN.SD	Algol IIIA Igniter	Consists of main propellant grain in igniter; a Safe and Arm device; an SRM chamber pressure transducer. One (1) Structural attach interface to motor, arming has pin interface and an initiator interface; initiator has interface to main igniter chamber, and one exit interface. And power interface and a chamber pressure transducer interfaces.
6744	ST.LV.A1.ME	Mechanisms	Scout Mechanisms Item
6745	ST.LV.A1.ME.AC	Access	
6746	ST.LV.A1.ME.AC.PN	Algol IIIA Transition Structure Access Panels	One panel in Transition A Base and one in Transition B structure. (Source: NASA CR-165950/Pt. 1, p. 26.)
6747	ST.LV.A1.ME.SX	Separation Mechanisms	(Source: NASA CR-165950/Pt. 1, p. 63.)
6748	ST.LV.A1.ME.SX.ME	Transition "B" Blowout Diaphragm	Diaphragm threaded to Transition "B" Lower structure. (Source: NASA CR-165950/Pt. 1, p. 26.)
6753	ST.LV.A1.PW	Power Management and Distribution	Scout Power Management and Distribution Item
6756	ST.LV.A1.PW.PD	Electrical/Ignition System	
6757	ST.LV.A1.PW.PD.35	Algol IIIA Electrical Power	A battery and an interlock, and a power interface to control system hyd pump. (Source: NASA CR-165950/Pt. 1, p. 91-92.)
6881	ST.LV.A1.PW.PD.35	Algol IIIA Ignition System Components	Includes monitor flyaway with two interfaces, ignition flyaway with one interface, and B section arming box with four interfaces, two igniters with one ordnance interface each. There is also a ground blockhouse interface. (Source: NASA CR-165950/Pt. 1, p. 91-92.)
6760	ST.LV.A1.CC	Instrumentation and Tracking	Scout Instrumentation and Tracking Item
6761	ST.LV.A1.CC.CD	Control and Data Management	
6762	ST.LV.A1.CC.CD.51	Algol IIIA Instrumentation	Includes first-stage boost parameters with a signal box and sensors. (Source: NASA CR-165950/Pt. 1, p. 95.)
6876	ST.LV.A1.CC.CR	Range Destruct Command	
6877	ST.LV.A1.CC.CR.RC	Algol IIIA Range Destruct Equipment	For first stage includes cabling in the tunnel, 1st stage pressure sw with 2 interfaces, a lanyard switch with two interfaces and cabling with two interfaces. (Source: NASA CR-165950/Pt. 1, Fig. 57, p. 94.)
6882	ST.LV.A1.TP	Passive Thermal Control	Scout Passive Thermal Control Item
6883	ST.LV.A1.TP.PN	Thermal Protection Subsystems	
6884	ST.LV.A1.TP.PN.29	Algol IIIA Thermal Protection Component Placeholder	
6885	ST.LV.A1.EC	Environmental Control	Scout Environmental Control Item

ACT_Id_No	Pedigree	Name	Description
6886	ST.LV.A1.EC.ET	Thermal Transport/Distribution	
6887	ST.LV.A1.EC.ET.79	Algol IIIA Thermal Control Placeholder	
6962	ST.LV.A2	Castor IIA Second Stage	
6999	ST.LV.A2.ST	Structures	Scout Structures Item
7000	ST.LV.A2.ST.SP	Primary Structures	
7004	ST.LV.A2.ST.SP.FH	Castor IIA Motor Case	Steel motor case interfaces to the Transition "B" upper section, lower Transition C structure, two tunnel mountings, and an ordnance interface with the motor propellant. The propellant charge is polybutadiene acrylic acid (PBAA) binder system. (Source: NASA CR-165950/Pt. 1, p. 63.)
7005	ST.LV.A2.ST.SP.FH	Transition Section "B" Upper Structure	Constructed of two glass-laminated clamshell sections which bolt to the Castor IIA motor case and encloses its nozzle. The case mounts four 40-lb roll motors, four 500-lb pitch and yaw motors, a H2O, a nitrogen pressurization system including N2 tank, and mountings for telemetry components (~13 mounting interfaces). NOTE: The interstitial space is not considered a confined space since there is no dedicated purge, no toxics to purge, and no personnel entry. It's a nonpurged space with external access only. (Source: NASA CR-165950/Pt. 1, p. 32.)
7006	ST.LV.A2.ST.SP.FH	Transition Section Lower "C" Structure	Provides primary load path between second and third stages of the Scout vehicle. Also, an interface to threaded diaphragm insert. Also, second stage mating structural mating interface. (Source: NASA CR-165950/Pt. 1, p. 26.)
7007	ST.LV.A2.ST.SP.39	Castor IIA Motor Nozzle	Lightweight internally insulated steel nozzle. (Source: NASA CR-165950/Pt. 1, p. 64.)
7002	ST.LV.A2.ST.SR	Range Destruct	
7009	ST.LV.A2.ST.SR.RD	Castor IIA Shaped Charges	There are two shaped charges. (Source: NASA CR-165950/Pt. 1, Fig. 57, p. 94.)
7003	ST.LV.A2.ST.SF	Fairing/Shrouds	
7010	ST.LV.A2.ST.SF.FX	Castor IIA Wiring Tunnel Covers	Two opposing wiring tunnels with structural interfaces to the motor case. Also, encases two ordnance shaped charges. (Source: NASA CR-165950/Pt. 1, Fig. 5, p. 6.)
7011	ST.LV.A2.MP	Propulsion – Maneuvering	Scout Propulsion – Maneuvering Item
7012	ST.LV.A2.MP.MN	Main Propulsion	
7013	ST.LV.A2.MP.MN.SD	Castor IIA Solid Motor Propellant	Propellant grain configuration consists of a cylindrical part with two radial slots. The propellant charge is a polybutadiene acrylic acid (PBAA) binder system. (Source: NASA CR-165950/Pt. 1, p. 64.)

ACT_Id_No	Pedigree	Name	Description
7014	ST.LV.A2.MP.MN.SD	Castor IIA Igniter	The igniter is a rocket motor type (pyrogen) with dual squib initiators. Consists of main propellant grain in igniter; a Safe and Arm device; an SRM chamber pressure transducer. One (1) structural attach interface to motor, arming has pin interface and an initiator interface; initiator has interface to main igniter chamber, and one exit interface. And power interface and a chamber pressure transducer interfaces.
7114	ST.LV.A2.MP.MS	Monopropellant Reaction Control Storage and Feed	Includes peroxide stage supply and feed to four roll motors and feed to four pitch-yaw motors.
7115	ST.LV.A2.MP.MS.FU	Peroxide (H2O2) Reaction Control Supply and Feed	Includes peroxide stage supply and feed to four roll motors and feed to four pitch-yaw motors. Mounted in the upper Transition Section B; and a fill and drain interface to ground
7116	ST.LV.A2.MP.MS.PE	Nitrogen (GN2) Storage and Pressurization System	System included a gas supply and pressurization feed system for the peroxide monprop. Also include ground fill point.
7117	ST.LV.A2.MP.ME	Second Stage Reaction Control Thrusters	
7118	ST.LV.A2.MP.ME.MP	Second Stage Roll Thrusters	Four second-stage 40-pound peroxide monopropellant motor/thrusters. Interfaces to fuel, mounting structure and command.
7119	ST.LV.A2.MP.ME.MP	Second Stage Pitch-Yaw Thrusters	Four pitch-yaw 400-pound thrust motor/thrusters. Interfaces to fuel supply, mounting and command.
7015	ST.LV.A2.ME	Mechanisms	Scout Mechanisms Item
7016	ST.LV.A2.ME.AC	Access	
7018	ST.LV.A2.ME.AC.PN	Castor IIA Transition Access Panels	One panel in Transition B Upper and one in Transition C lower structure. (Source: NASA CR-165950/Pt. 1, p. 26.)
7017	ST.LV.A2.ME.SX	Separation Mechanisms	(Source: NASA CR-165950/Pt. 1, p. 63.)
7019	ST.LV.A2.ME.SX.ME	Transition "C" Blowout Diaphragm	Diaphragm threaded to Transition "C" Lower structure. (Source: NASA CR-165950/Pt. 1, p. 32.)
7020	ST.LV.A2.PW	Power Management and Distribution	Scout Power Management and Distribution Item
7021	ST.LV.A2.PW.PD	Electrical/Ignition System	
7022	ST.LV.A2.PW.PD.35	Castor IIA Electrical Power	No batteries in the second stage upper and lower transition structures. Cabling only. (Source: NASA CR-165950/Pt. 1, p. 94.)
7023	ST.LV.A2.PW.PD.35	Castor IIA Ignition System Components	There are two second stage igniters and a C section arming box and cabling with interfaces between them and to the D section arming box and Power Control Relay box. (Source: NASA CR-165950/Pt. 1, p. 91-92.)
7024	ST.LV.A2.CC	Instrumentation and Tracking	Scout Instrumentation and Tracking Item

ACT_Id_No	Pedigree	Name	Description
7025	ST.LV.A2.CC.CD	Control and Data Management	
7027	ST.LV.A2.CC.CD.51	Castor IIA Instrumentation	Lower C transition section includes ignition arming relay status, second stage headcap pressure switch, and the telemetry second stage headcap pressure transducer (signal box and sensors). (Source: NASA CR-165950/Pt. 1, p. 32, and 95.)
7026	ST.LV.A2.CC.CR	Range Destruct Command	
7028	ST.LV.A2.CC.CR.RC	Castor IIA Range Destruct Equipment	For second stage includes cabling in the tunnel, 2nd stage pressure sw with 2 interfaces, a lanyard switch with two interfaces and cabling with two interfaces. (Source: NASA CR-165950/Pt. 1, Fig. 57, p. 94.)
7029	ST.LV.A2.TP	Passive Thermal Control	Scout Passive Thermal Control Item
7030	ST.LV.A2.TP.PN	Thermal Protection Subsystems	
7031	ST.LV.A2.TP.PN.29	Castor IIA Thermal Protection Component Placeholder	
7032	ST.LV.A2.EC	Environmental Control	Scout Environmental Control Item
7033	ST.LV.A2.EC.ET	Thermal Transport/Distribution	
7034	ST.LV.A2.EC.ET.79	Castor IIA Thermal Control Placeholder	
7035	ST.LV.A3	Antares IIA Third Stage	
7036	ST.LV.A3.ST	Structures	Scout Structures Item
7037	ST.LV.A3.ST.SP	Primary Structures	
7041	ST.LV.A3.ST.SP.FH	Antares IIA Motor Case	“Reinforced plastics” motor case interfaces to the upper Transition “C” section, lower Transition D structure, two tunnel mountings, and an ordnance interface with the motor propellant. (Source: NASA CR-165950/Pt. 1, p. 32 and 63.)
7042	ST.LV.A3.ST.SP.FH	Transition Section "C" Upper Structure	The Upper Transition “C” section is a slightly tapered cylindrical structure having an aluminum and phenolic framework covered with phenolic glass (with gold plating interior, system FOM is four materials). The forward end bolts to the aft end of the third stage rocket motor case and the inside aft end is threaded and connects to lower Transition “C” by means of the frangible diaphragm. Upper “C” contains ignition batteries, guidance rate gyros, diode unit, reaction control fuel and motor system, command destruct receiving and initiating system, and telemetering components. Removable panels provide access to interior components. (Source: NASA CR-165950/Pt. 1, p. 32.)

ACT_Id_No	Pedigree	Name	Description
7043	ST.LV.A3.ST.SP.FH	Transition Section Lower "D" Structure	The aft end of the lower Transition “D” structure bolts to the third stage rocket motor case and forward end supports the spin bearing. Lower section “D” contains ignition, guidance, and telemetering components, including such components as a guidance programmer, inertial reference package, poppet valve electronics, intervalometer, inverter, telemetering package, F/M transmitter, and radar beacon. The inner surfaces of the section are coated with mirror-like gold finish to provide emissivity for thermal protection of the components. Removable panels provide access to components. (Source: NASA CR-165950/Pt. 1, p. 32.)
7044	ST.LV.A3.ST.SP.39	Antares IIA Motor Nozzle	Lightweight reinforced plastic nozzle. (Source: NASA CR-165950/Pt. 1, p. 63.)
7039	ST.LV.A3.ST.SR	Range Destruct	
7046	ST.LV.A3.ST.SR.RD	Antares IIA Shaped Charges	There are two shaped charges. (Source: NASA CR-165950/Pt. 1, Fig. 57, p. 94.)
7040	ST.LV.A3.ST.SF	Fairing/Shrouds	
7047	ST.LV.A3.ST.SF.FX	Antares IIA Wiring Tunnel Covers	Two opposing wiring tunnels with structural interfaces to the motor case. Also, encloses two ordnance shaped charges. (Source: NASA CR-165950/Pt. 1, Fig. 5, p. 6.)
7048	ST.LV.A3.MP	Propulsion – Maneuvering	Scout Propulsion – Maneuvering Item
7049	ST.LV.A3.MP.MN	Main Propulsion	
7050	ST.LV.A3.MP.MN.SD	Antares IIA Solid Motor Propellant	The composite modified double base propellant is a case-bonded slotted-cylinder grain configuration. (Source: NASA CR-165950/Pt. 1, p. 65.)
7051	ST.LV.A3.MP.MN.SD	Antares IIA Igniter	Ignition is accomplished by a dual squib rock motor type igniter. One (1) structural attach interface to motor, arming has pin interface and an initiator interface; initiator has interface to main igniter chamber, and one exit interface. And power interface and a chamber pressure transducer interfaces.
7126	ST.LV.A3.MP.MS	Monopropellant Reaction Control Storage and Feed	Includes peroxide stage supply and feed to four roll motors and feed to four pitch-yaw motors.
7127	ST.LV.A3.MP.MS.FU	Peroxide (H2O2) Reaction Control Supply and Feed	Includes peroxide stage supply and feed to four roll motors and feed to four pitch-yaw motors. Mounted in the upper Transition Section C; and a fill and drain interface to ground.
7128	ST.LV.A3.MP.MS.PE	Nitrogen (GN2) Storage and Pressurization System	System included a gas supply and pressurization feed system for the peroxide monprop. Also includes ground fill point.
7129	ST.LV.A3.MP.ME	Third Stage Reaction Control Thrusters	

ACT_Id_No	Pedigree	Name	Description
7130	ST.LV.A3.MP.ME.MP	Third Stage Roll Thrusters	Four second-stage 14-pound peroxide monopropellant motor/thrusters. Interfaces to fuel, mounting structure and command.
7131	ST.LV.A3.MP.ME.MP	Third Stage Pitch-Yaw Thrusters	Four pitch-yaw 40-pound thrust motor/thrusters. Interfaces to fuel supply, mounting and command.
7052	ST.LV.A3.ME	Mechanisms	Scout Mechanisms Item
7053	ST.LV.A3.ME.AC	Access	
7055	ST.LV.A3.ME.AC.PN	Antares IIA Transition C/D Access Panels	Two panels in Upper Transition C and two in Lower Transition D structure. (Source: NASA CR-165950/Pt. 1, p. 26.)
7054	ST.LV.A3.ME.SX	Separation Mechanisms	(Source: NASA CR-165950/Pt. 1, p. 63.)
7056	ST.LV.A3.ME.SX.ME	Cold Separation System	The third and fourth stages are joined by a "cold separation" arrangement of ejector springs (32) held compressed by a set of securing clamps. Explosive bolts release the clamps, effecting separation by this method also. (system count of two: spring ejector and explosive bolt/clamps). (Source: NASA CR-165950/Pt. 1, Fig. 53., p. 90.)
7057	ST.LV.A3.PW	Power Management and Distribution	Scout Power Management and Distribution Item
7058	ST.LV.A3.PW.PD	Electrical/Ignition System	
7059	ST.LV.A3.PW.PD.35	Antares IIA Electrical Power	There were two ignition batteries in the upper Transition C section, a power control relay box, a 28 V battery, and a 37 V battery, as well as associated cabling/harnesses. (Source: NASA CR-165950/Pt. 1, p. 91-92.)
7060	ST.LV.A3.PW.PD.35	Antares IIA Ignition System Components	Includes interfaces to ignition batteries, 3rd stage igniters, D section arming box, interfaces to C section arming box and 12 position Ledex box. (Source: NASA CR-165950/Pt. 1, p. 91-92.)
7061	ST.LV.A3.CC	Instrumentation and Tracking	Scout Instrumentation and Tracking Item.
7062	ST.LV.A3.CC.CD	Control and Data Management	
7064	ST.LV.A3.CC.CD.51	Antares IIA Instrumentation	Includes instrumentation associated with and centralized in the third stage transition sections for: guidance and control avionics, range destruct command, telemetering, and RF antenna functions. Also includes sensors for reaction control status (Source: NASA CR-165950/Pt. 1, p. 95.)
7063	ST.LV.A3.CC.CR	Range Destruct Command	

ACT_Id_No	Pedigree	Name	Description
7065	ST.LV.A3.CC.CR.RC	Antares IIA Range Destruct Equipment	For third stage includes cabling in the tunnel, 3rd stage pressure sw with 2 interfaces, a lanyard switch with two interfaces and cabling with two interfaces. (Source: NASA CR-165950/Pt. 1, Fig. 57, p. 94.)
7112	ST.LV.A3.CC.CT	Comm & Tracking	
7113	ST.LV.A3.CC.CT.FM	Radar Tracking Beacon System	The beacon has a nominal power output of 1/2 kilowatt, single pulse; a blade type antenna is used and mounted in the lower Transition D section. There is also a mixer, a subcarrier oscillator package, voltage reference supply, calibrator which interfaces to the instrumentation/telemeter system onboard.
7066	ST.LV.A3.TP	Passive Thermal Control	Scout Passive Thermal Control Item
7067	ST.LV.A3.TP.PN	Thermal Protection Subsystems	
7068	ST.LV.A3.TP.PN.29	Antares IIA Thermal Protection Component Placeholder	
7069	ST.LV.A3.EC	Environmental Control	Scout Environmental Control Item
7070	ST.LV.A3.EC.ET	Thermal Transport/Distribution	
7071	ST.LV.A3.EC.ET.79	Antares IIA Thermal Control Placeholder	
7072	ST.LV.A4	Altair IIIA Fourth Stage	
7073	ST.LV.A4.ST	Structures	Scout Structures Item
7074	ST.LV.A4.ST.SP	Primary Structures	
7078	ST.LV.A4.ST.SP.FH	Altair IIIA Motor Case	Fiberglass filament wound motor case interfaces to upper section D and to the payload adapter base structure (section E). (Source: NASA CR-165950/Pt. 1, Fig 5, p. 6, p.33)
7079	ST.LV.A4.ST.SP.FH	Transition Section "D" Upper Structure	Upper D is divided into two sections at the mating plane of the third and fourth stages and is held together by an explosive bolt-secured clamp which provides stage separation. The lower section contains four rocket spin motors and its aft end is attached to the spin bearing. The upper section bolts to the fourth stage rocket motor. The upper stage has an optional system for measurement of vehicle fourth stage performance and a complete dualized separation system. Upper D is covered by the heat shield (payload fairing) when the vehicle is assembled. (Source: NASA CR-165950/Pt. 1, p. 32.)

ACT_Id_No	Pedigree	Name	Description
7080	ST.LV.A4.ST.SP.FH	Transition Section "E" Payload Adapter	Provides primary load path between fourth stage and the payload. The basic adapter (four adapters were available) assembly consists of a conical adapter, a payload support ring, and a separation clamp. The adapter base is bolted directly to the fourth stage motor case forward flange. The payload support ring provides threaded holes to attachment to the payload and machined surfaces for mating to top of the adapter. The payload separation clamp is a two-piece assembly. When bolted together, this clamp holds payload support ring and adapter together. The clamp configuration allows removal of the payload from the vehicle. The separation system springs provide sufficient energy to impart a relative separation velocity of 3.4 feet per second to a 200-pound spacecraft. (Source: NASA CR-165950/Pt. 1, p. 32-33.)
7081	ST.LV.A4.ST.SP.39	Altair IIIA Motor Nozzle	(Source: NASA CR-165950/Pt. 1, p. 69.)
7109	ST.LV.A4.ST.SP.39	Fourth Stage Spin Table Structure	(Source: NASA CR-165950/Pt. 1, p. 33, p. 87, Fig. 53., p. 90.)
7076	ST.LV.A4.ST.SR	Range Destruct	
7083	ST.LV.A4.ST.SR.RD	Altair IIIA Range Destruct	None. (Source: NASA CR-165950/Pt. 1, Fig. 57, p. 94.)
7132	ST.LV.A4.ST.SF	Fixed Fairings/Shrouds	
7133	ST.LV.A4.ST.SF.FX	Heat Shield (Payload Fairing)	Used five different diameters: 20, 21.5, 25.7, 34, and 42-in diameter shields. Fabricated from two fiberglass honeycomb half shells. The 34-in version had a stainless steel nose cap and the 42-in version had a cork-covered aluminum nose cap. There were two halves and attachment/separation hardware (s systems) and three interfaces. (Source: NASA CR-165950/Pt. 1, p. 33.)
7085	ST.LV.A4.MP	Propulsion – Maneuvering	Scout Propulsion – Maneuvering Item
7086	ST.LV.A4.MP.MN	Main Propulsion	
7087	ST.LV.A4.MP.MN.SD	Altair IIIA Solid Motor Propellant	The PBAN (polybutadiene acrylic acid – Acrilonitrile) composite propellant grain configuration is a case-bonded circular perforation with one transverse slot. (Source: NASA CR-165950/Pt. 1, p. 69.)

ACT_Id_No	Pedigree	Name	Description
7088	ST.LV.A4.MP.MN.SD	Altair IIIA igniter	Consists of main propellant grain in igniter; a Safe and Arm device; an SRM chamber pressure transducer. One (1) Structural attach interface to motor, arming has pin interface and an initiator interface; initiator has interface to main igniter chamber, and one exit interface. And power interface and a chamber pressure transducer interfaces.
7089	ST.LV.A4.ME	Mechanisms	Scout Mechanisms Item
7090	ST.LV.A4.ME.AC	Access	
7092	ST.LV.A4.ME.AC.PN	Altair IIIA Transition D Access Panels	Two panels in Transition D upper section. (Source: NASA CR-165950/Pt. 1, p. 26.)
7091	ST.LV.A4.ME.SX	Separation Mechanisms	(Source: NASA CR-165950/Pt. 1, p. 63.)
7093	ST.LV.A4.ME.SX.ME	Payload Separation	Separation was through separation spring system. (Source: NASA CR-165950/Pt. 1, p. 26.)
7110	ST.LV.A4.ME.AD	Element Spin Mechanisms	
7111	ST.LV.A4.ME.AD.19	Fourth Stage Spin Table Bearing	
7094	ST.LV.A4.PW	Power Management and Distribution	Scout Power Management and Distribution Item
7095	ST.LV.A4.PW.PD	Electrical/Ignition System	
7096	ST.LV.A4.PW.PD.35	Altair IIIA Electrical Power	(Source: NASA CR-165950/Pt. 1, Fig. 54, p. 91-92.)
7097	ST.LV.A4.PW.PD.35	Altair IIIA Ignition System Components	System included 4th stage igniters, spin motor igniters and interfaces to section d arming box and separation bolts. (Source: NASA CR-165950/Pt. 1, p. 91-92.)
7098	ST.LV.A4.CC	Instrumentation and Tracking	Scout Instrumentation and Tracking Item
7099	ST.LV.A4.CC.CD	Control and Data Management	
7101	ST.LV.A4.CC.CD.51	Altair IIIA Instrumentation	Includes fourth stage boost parameters with a signal box and sensors. (Source: NASA CR-165950/Pt. 1, p. 95.)
7103	ST.LV.A4.TP	Passive Thermal Control	Scout Passive Thermal Control Item
7104	ST.LV.A4.TP.PN	Thermal Protection Subsystems	
7105	ST.LV.A4.TP.PN.29	Altair IIIA Thermal Protection Component Placeholder	
7106	ST.LV.A4.EC	Environmental Control	Scout Environmental Control Item
7107	ST.LV.A4.EC.ET	Thermal Transport/Distribution	
7108	ST.LV.A4.EC.ET.79	Altair IIIA Thermal Control Placeholder	

APPENDIX B. FOUR-STAGE ALL-SOLID NANOLAUNCHER, NL001, DEFINITION SHEET

(created w/ACT prototype)

ACT_Id_No	Pedigree	Name	Description
10700	ST	NL Concept 1 (NL001.1)	Nanolauncher Study, Phase 1/Four-Stage All-Solid
10706	ST.SP	Nanolauncher Payload Class	
10707	ST.SP.PM	Nanolauncher Payload Element	
10708	ST.SP.PM.GP	Nanolauncher Payload Systems	
10709	ST.SP.PM.GP.GI	Nanolauncher Shrouded Payload	
10710	ST.SP.PM.GP.GI.UP	Nanolauncher Payload	
11189	ST.SP.PM.ST	Payload Accommodation – 3xCubeSat P-Pod	
11190	ST.SP.PM.ST.SP	Payload Structural Accommodation	
11191	ST.SP.PM.ST.SP.HT	Payload Adapter Structure	
10711	ST.LV	NL Configuration 1 Launch Vehicle (NL001.1)	
10712	ST.LV.A1	First Stage-Solid	
10713	ST.LV.A1.ST	Body Structure	
10714	ST.LV.A1.ST.SP	Primary Load-Bearing Structure	
10777	ST.LV.A1.ST.SP.FH	First Stage Forward Interstage Structure	Provides primary load path between first and second stages of the NL Configuration 1 vehicle.
10778	ST.LV.A1.ST.SP.FH	First Stage Aft Skirt Structure	Reinforced for stabilizer fins.
10839	ST.LV.A1.ST.SF	Secondary Structure	
10840	ST.LV.A1.ST.SF.FX	First Stage Systems Tunnel Cover/Fairing	
10718	ST.LV.A1.MP	Main Propulsion	
10841	ST.LV.A1.MP.MD	Propellant Storage	
10842	ST.LV.A1.MP.MD.67	First Stage Solid Rocket Motor Case Structure	
10843	ST.LV.A1.MP.MD.68	First Stage Solid Rocket Motor Case Insulation	
10844	ST.LV.A1.MP.MN	Thrust Generation/Engine – Combustion	(Accomplished in motor case.)
10846	ST.LV.A1.MP.MN.SD	First Stage Solid Motor (Functional Placeholder)	
10845	ST.LV.A1.MP.MN	Thrust Generation/Engine – Nozzle/exhaust gas management	
10847	ST.LV.A1.MP.MN.SD	First Stage SRM Exhaust Nozzle	
10848	ST.LV.A1.MP.MN	Thrust Generation/Engine – Engine Start	Main chamber or preburner/gas-generator).
10849	ST.LV.A1.MP.MN.SD	First Stage SRM Igniter System	
10850	ST.LV.A1.MP.MN	Propulsion System Control and Health Management	
10851	ST.LV.A1.MP.MN.SD	First Stage SRM Sensors	Chamber pressure, etc.

ACT_Id_No	Pedigree	Name	Description
11215	ST.LV.A1.MP.MD	Main Propellant Function	
11217	ST.LV.A1.MP.MD.67	First Stage Solid Propellant	
10724	ST.LV.A1.PW	Electrical Power Generation, Control and Distribution	
10725	ST.LV.A1.PW.PD	Electrical Power Distribution	
10789	ST.LV.A1.PW.PD.35	First Stage Electrical Power Cabling	Ignition power is provided from ground or from upstage source carried through the wiring tunnel covers.
10852	ST.LV.A1.TP	Thermal Control	
10853	ST.LV.A1.TP.PN	Passive Thermal Protection	
10854	ST.LV.A1.TP.PN.BL	Thermal Blanket TPS Components	(Only for pad launch option.)
10855	ST.LV.A1.EC	Environmental Control	
10857	ST.LV.A1.EC.EP	Pressure Control	
10858	ST.LV.A1.EC.EP.OV	First Stage Interstage Outlets and Vents	
10859	ST.LV.A1.CC	Flight Stabilization and Control	
10860	ST.LV.A1.CC.CG	Stabilization	Vehicle aerodynamic and spin stabilization.
10861	ST.LV.A1.CC.CG.59	First Stage Fixed Stabilizer Fins	
10862	ST.LV.A1.CC.CG.59	First Stage Spin-up Motors	With mountings (located in First Stage Forward Interstage).
10863	ST.LV.A1.CC	Command and Data Management	
10864	ST.LV.A1.CC.CD	Command and Data Distribution	
10865	ST.LV.A1.CC.CD.51	First Stage Command and Data Cabling/Wiring	
10866	ST.LV.A1.CC	Flight Termination	
10867	ST.LV.A1.CC.CR	Destruct Systems	
10868	ST.LV.A1.CC.CR.RC	First Stage Destruct Command Electronics	Not included in First Stage.
10869	ST.LV.A1.CC.CR.55	First Stage Destruct Equipment	May not be needed for rail launch.
10870	ST.LV.A1.ME	Stage/Element Separation	
10871	ST.LV.A1.ME.SX	Non-Ordnance Stage Separation	
10872	ST.LV.A1.ME.SX.ME	First Stage Mechanical Separation Components	Spring sets.
10873	ST.LV.A1.ME.SX	Ordnance Stage Separation	
10874	ST.LV.A1.ME.SX.OR	First Stage Ordnance Separation Components	Pyrotechnical devices requiring special keep out zone, work stoppage operations, dedicated ordnance storage facilities, and ground equipment.
10876	ST.LV.A1.RL	Launch/Takeoff and Landing Support	
10877	ST.LV.A1.RL.RG	Launch Support	
10878	ST.LV.A1.RL.RG.105	Launch Rail-First Stage Structural/Mechanical Interface Components	
10926	ST.LV.A1	Second Stage – Solid	

ACT_Id_No	Pedigree	Name	Description
10927	ST.LV.A1.ST	Body Structure	
10928	ST.LV.A1.ST.SP	Primary Load-Bearing Structure	
10953	ST.LV.A1.ST.SP.FH	Second Stage Forward Interstage Structure	Provides primary load path between first and second stages of the NL Configuration 1 vehicle.
10954	ST.LV.A1.ST.SP.FH	Second Stage Aft Interstage Structure	Reinforced for stabilizer fins.
10929	ST.LV.A1.ST.SF	Secondary Structure	
10955	ST.LV.A1.ST.SF.FX	Second Stage Systems Tunnel Cover/Fairing	
10973	ST.LV.A1.ST.SF.43	Second Stage Forward Interstage Access Panels	
10974	ST.LV.A1.ST.SF.44	Second Stage Aft Interstage Access Panels	
10930	ST.LV.A1.MP	Main Propulsion	
10931	ST.LV.A1.MP.MD	Propellant Storage	
10956	ST.LV.A1.MP.MD.67	Second Stage Solid Rocket Motor Case Structure	
10957	ST.LV.A1.MP.MD.68	Second Stage Solid Rocket Motor Case Insulation	
10932	ST.LV.A1.MP.MN	Thrust Generation/Engine – Combustion	(Accomplished in motor case.)
10958	ST.LV.A1.MP.MN.SD	Second Stage Solid Motor (Functional Placeholder)	
10933	ST.LV.A1.MP.MN	Thrust Generation/Engine – Nozzle/exhaust gas management	
10959	ST.LV.A1.MP.MN.SD	Second Stage SRM Exhaust Nozzle	
10934	ST.LV.A1.MP.MN	Thrust Generation/Engine – Engine Start	Main chamber or preburner/gas-generator).
10960	ST.LV.A1.MP.MN.SD	Second Stage SRM Igniter System	
10935	ST.LV.A1.MP.MN	Propulsion System Control and Health Management	
10961	ST.LV.A1.MP.MN.SD	Second Stage SRM Sensors	Chamber pressure, etc.
10936	ST.LV.A1.PW	Electrical Power Generation, Control and Distribution	
10937	ST.LV.A1.PW.PD	Electrical Power Distribution	
10962	ST.LV.A1.PW.PD.35	Second Stage Electrical Power Cabling	Ignition power is provided from ground or from upstage source carried through the wiring tunnel covers.
10940	ST.LV.A1.EC	Environmental Control	
10941	ST.LV.A1.EC.EP	Pressure Control	
10964	ST.LV.A1.EC.EP.OV	Second Stage Interstage Outlets and Vents	
10942	ST.LV.A1.CC	Flight Stabilization and Control	
10943	ST.LV.A1.CC.CG	Stabilization	Vehicle aerodynamic stabilization may be required.

ACT_Id_No	Pedigree	Name	Description
10965	ST.LV.A1.CC.CG.59	Second Stage Fixed Stabilizer Fins	
10944	ST.LV.A1.CC	Command and Data Management	
10945	ST.LV.A1.CC.CD	Command and Data Distribution	
10967	ST.LV.A1.CC.CD.51	Second Stage Command and Data Cabling/Wiring	
10946	ST.LV.A1.CC	Flight Termination	
10947	ST.LV.A1.CC.CR	Destruct Systems	
10968	ST.LV.A1.CC.CR.RC	Second Stage Destruct Command Electronics	
10969	ST.LV.A1.CC.CR.55	Second Stage Destruct Equipment	
10948	ST.LV.A1.ME	Stage/Element Separation	
10949	ST.LV.A1.ME.SX	Non-Ordnance Stage Separation	
10970	ST.LV.A1.ME.SX.ME	Second Stage Mechanical Separation Components	Spring sets.
10950	ST.LV.A1.ME.SX	Ordnance Stage Separation	
10971	ST.LV.A1.ME.SX.OR	Second Stage Ordnance Separation Components	Pyrotechnical devices requiring special keep out zone, work stoppage operations, dedicated ordnance storage facilities, and ground equipment.
10951	ST.LV.A1.RL	Launch/Takeoff and Landing Support	
10952	ST.LV.A1.RL.RG	Launch Support	
10972	ST.LV.A1.RL.RG.105	Launch Rail-Second Stage Structural/Mechanical Interface Components	
11020	ST.LV.A1	Third Stage – Solid	
11021	ST.LV.A1.ST	Body Structure	
11022	ST.LV.A1.ST.SP	Primary Load-Bearing Structure	
11045	ST.LV.A1.ST.SP.FH	Third Stage Forward Interstage Structure	Provides primary load path between first and second stages of the NL Configuration 1 vehicle.
11046	ST.LV.A1.ST.SP.FH	Third Stage Aft Interstage Structure	Reinforced for stabilizer fins.
11065	ST.LV.A1.ST.SP.FH	Third Stage/Fourth Stage Adapter Structure	
11023	ST.LV.A1.ST.SF	Secondary Structure	
11047	ST.LV.A1.ST.SF.FX	Third Stage Systems Tunnel Cover/Fairing	
11048	ST.LV.A1.ST.SF.43	Third Stage Forward Interstage Access Panels	
11049	ST.LV.A1.ST.SF.44	Third Stage Aft Interstage Access Panels	
11024	ST.LV.A1.MP	Main Propulsion	
11025	ST.LV.A1.MP.MD	Propellant Storage	

ACT_Id_No	Pedigree	Name	Description
11050	ST.LV.A1.MP.MD.67	Third Stage Solid Rocket Motor Case Structure	
11051	ST.LV.A1.MP.MD.68	Third Stage Solid Rocket Motor Case Insulation	
11026	ST.LV.A1.MP.MN	Thrust Generation/Engine – Combustion	(Accomplished in motor case.)
11052	ST.LV.A1.MP.MN.SD	Third Stage Solid Motor (Functional Placeholder)	
11027	ST.LV.A1.MP.MN	Thrust Generation/Engine – Nozzle/exhaust gas management	
11053	ST.LV.A1.MP.MN.SD	Third Stage SRM Exhaust Nozzle	
11028	ST.LV.A1.MP.MN	Thrust Generation/Engine – Engine Start	Main chamber or preburner/gas-generator).
11054	ST.LV.A1.MP.MN.SD	Third Stage SRM Igniter System	
11029	ST.LV.A1.MP.MN	Propulsion System Control and Health Management	
11055	ST.LV.A1.MP.MN.SD	Third Stage SRM Sensors	Chamber pressure, etc.
11030	ST.LV.A1.PW	Electrical Power Generation, Control and Distribution	
11031	ST.LV.A1.PW.PD	Electrical Power Distribution	
11056	ST.LV.A1.PW.PD.35	Third Stage Electrical Power Cabling	Ignition power is provided from ground or from upstage source carried through the wiring tunnel covers.
11068	ST.LV.A1.PW.PD.E1	Third Stage Distributed/remote power controllers/switch gear	
11066	ST.LV.A1.PW.ES	Energy/Power Source	
11067	ST.LV.A1.PW.ES.BT	Third Stage Batteries	Electrochemical (primary vehicle electric power).
11032	ST.LV.A1.EC	Environmental Control	
11033	ST.LV.A1.EC.EP	Pressure Control	
11057	ST.LV.A1.EC.EP.OV	Third Stage Interstage Outlets and Vents	
11034	ST.LV.A1.CC	Flight Stabilization and Control	
11035	ST.LV.A1.CC.CG	Stabilization	Vehicle aerodynamic and spin stabilization.
11058	ST.LV.A1.CC.CG.59	Third Stage De-Spin/Yo-Yo	
11036	ST.LV.A1.CC	Command and Data Management	
11037	ST.LV.A1.CC.CD	Command and Data Distribution	
11059	ST.LV.A1.CC.CD.51	Third Stage Command and Data Cabling/Wiring	
11069	ST.LV.A1.CC.CT	Communications and Tracking	
11070	ST.LV.A1.CC.CT.CB	C-Band Tracking Transponder and Antennas	For radar tracking.
11071	ST.LV.A1.CC.CT.SB	S-Band Telemetry Transmitter and Antennas	Range-required telemetry and customer-required telemetry in the same data stream.

ACT_Id_No	Pedigree	Name	Description
11072	ST.LV.A1.CC.CT.UH	UHF Flight Termination receiver and antennas for FTS command destruct	
11073	ST.LV.A1.CC.CT.53	GPS Antennas and Electronics	For navigation.
11038	ST.LV.A1.CC	Flight Termination	
11039	ST.LV.A1.CC.CR	Destruct Systems	
11060	ST.LV.A1.CC.CR.RC	Third Stage Destruct Command Electronics	AFSS
11061	ST.LV.A1.CC.CR.55	Third Stage Destruct Equipment (Ordnance)	
11074	ST.LV.A1.CC.CR.56	Fourth Stage Destruct Equipment (Ordnance)	
11040	ST.LV.A1.ME	Stage/Element Separation	
11041	ST.LV.A1.ME.SX	Non-Ordnance Stage Separation	
11062	ST.LV.A1.ME.SX.ME	Third Stage Mechanical Separation Components	Spring sets.
11042	ST.LV.A1.ME.SX	Ordnance Stage Separation	
11063	ST.LV.A1.ME.SX.OR	Third Stage Ordnance Separation Components	Pyrotechnical devices requiring special keep-out zone, work stoppage operations, dedicated ordnance storage facilities, and ground equipment.
11127	ST.LV.A1	Fourth Stage – Solid	
11128	ST.LV.A1.ST	Body Structure	
11129	ST.LV.A1.ST.SP	Primary Load-Bearing Structure	
11179	ST.LV.A1.ST.SP.SJ	Fourth Stage Adapter Ring Structure	
11131	ST.LV.A1.MP	Main Propulsion	
11132	ST.LV.A1.MP.MD	Propellant Storage	
11158	ST.LV.A1.MP.MD.67	Fourth Stage Solid Rocket Motor Case Structure	
11159	ST.LV.A1.MP.MD.68	Fourth Stage Solid Rocket Motor Case Insulation	
11133	ST.LV.A1.MP.MN	Thrust Generation/Engine – Combustion	(Accomplished in motor case.)
11160	ST.LV.A1.MP.MN.SD	Fourth Stage Solid Motor (Functional Placeholder)	
11134	ST.LV.A1.MP.MN	Thrust Generation/Engine – Nozzle/exhaust gas management	
11161	ST.LV.A1.MP.MN.SD	Fourth Stage SRM Exhaust Nozzle	
11135	ST.LV.A1.MP.MN	Thrust Generation/Engine – Engine Start	Main chamber or preburner/gas-generator).
11162	ST.LV.A1.MP.MN.SD	Fourth Stage SRM Igniter System	
11136	ST.LV.A1.MP.MN	Propulsion System Control and Health Management	
11163	ST.LV.A1.MP.MN.SD	Fourth Stage SRM Sensors	Chamber pressure, etc.

ACT_Id_No	Pedigree	Name	Description
11137	ST.LV.A1.PW	Electrical Power Generation, Control and Distribution	
11138	ST.LV.A1.PW.PD	Electrical Power Distribution	
11164	ST.LV.A1.PW.PD.35	Fourth Stage Electrical Power Cabling	Ignition power is provided from ground or from upstage source carried through the wiring tunnel covers.
11139	ST.LV.A1.PW.ES	Energy/Power Source	
11166	ST.LV.A1.PW.ES.BT	Fourth Stage Batteries	Electrochemical (primary vehicle electric power).
11142	ST.LV.A1.CC	Flight Stabilization and Control	
11143	ST.LV.A1.CC.CG	Attitude Control	
11168	ST.LV.A1.CC.CG.59	Fourth Stage Attitude Control Jets	
11180	ST.LV.A1.CC.CG.59	Fourth Stage Attitude Control Propellant Storage and Distribution	
11144	ST.LV.A1.CC	Command and Data Management	
11145	ST.LV.A1.CC.CD	Command and Data Distribution	
11169	ST.LV.A1.CC.CD.51	Fourth Stage Command and Data Cabling/Wiring	
11181	ST.LV.A1.CC.CD.CM	Vehicle Systems Interface Components	
11182	ST.LV.A1.CC.CD.GC	Ground Interface Components	
11183	ST.LV.A1.CC.CD.CM	Central Processing and Storage Components	
11146	ST.LV.A1.CC.CT	Communications and Tracking	
11173	ST.LV.A1.CC.CT.53	GPS Antennas and Electronics	For navigation.
11184	ST.LV.A1.CC	Guidance and Navigation	
11185	ST.LV.A1.CC.CD	Guidance and Navigation Computing and Sensors	
11186	ST.LV.A1.CC.CD.GD	G&N Flight Computer, Drivers, Amplifiers	
11187	ST.LV.A1.CC.CD.GD	Dedicated Inertial Measurement Devices	If not located in G&N flight computer.
11188	ST.LV.A1.CC.CD.51	Fourth Stage GPS Equipment	
11194	ST.LV.A3	Payload Fairing	
11195	ST.LV.A3.ST	Body Structure	
11196	ST.LV.A3.ST.SP	Primary Load Bearing Structure	
11197	ST.LV.A3.ST.SP.39	Payload Fairing Structure	
11198	ST.LV.A3.ST.SF	Secondary Structure	
11199	ST.LV.A3.ST.SF.43	Payload Fairing Access Panels	Also for Fourth Stage access.
11200	ST.LV.A3.TP	Thermal Control	
11203	ST.LV.A3.TP.AB	External Thermal Protection	
11205	ST.LV.A3.TP.AB.27	Payload Fairing Ablative Layer/Coating	
11204	ST.LV.A3.TP.PN	Internal Insulation	
11206	ST.LV.A3.TP.PN.BL	Payload Fairing Thermal Blankets/Insulation	

ACT_Id_No	Pedigree	Name	Description
11207	ST.LV.A3.EC	Environmental Control	
11208	ST.LV.A3.EC.EP	Pressure Stabilization	
11209	ST.LV.A3.EC.EP.OV	Payload Fairing Outlets/Vents	
11210	ST.LV.A3.EC.EP	Acoustic Environmental Control	
11211	ST.LV.A3.EC.EP.83	Payload Fairing Acoustic Blankets/Insulation	
11212	ST.LV.A3.ME	Element/Stage Separation	
11213	ST.LV.A3.ME.SX	Element Separation	
11214	ST.LV.A3.ME.SX.OR	Payload Fairing Ordnance Separation	

APPENDIX C. TWO-STAGE ALL-LIQUID LAUNCH VEHICLE, NL002, DEFINITION SHEET

(created w/ACT prototype)

ACT_Id_No	Pedigree	Name	Description
12106	ST	NL Concept 2 (NL002.1)	Nanolauncher Study, Phase I, Concept 2/Two-Stage All-Liquid
12107	ST.SP	Nanolauncher Payload Class	
12108	ST.SP.PM	Nanolauncher Payload Element	
12109	ST.SP.PM.GP	Nanolauncher Payload Systems	
12110	ST.SP.PM.GP.GI	Nanolauncher Shrouded Payload	
12111	ST.SP.PM.GP.GI.UP	Nanolauncher Payload	
12156	ST.SP.PM.ST	Payload Accommodation	
12157	ST.SP.PM.ST.SP	Payload Structural Accommodation	
12158	ST.SP.PM.ST.SP.HT	Payload Adapter Structure – 3xCubeSat P-Pod	
12112	ST.LV	NL Configuration 2 Launch Vehicle (NL002.1)	
12457	ST.LV.A1	First Stage – LOX/RP	
12458	ST.LV.A1.ST	Body Structure	
12459	ST.LV.A1.ST.SP	Primary Load-Bearing Structure	
12485	ST.LV.A1.ST.SP.FH	First Stage Forward Interstage Structure	Provides primary load path between first and second stages of the NL Configuration 2 vehicle.
12486	ST.LV.A1.ST.SP.FH	First Stage Aft Skirt Structure	Reinforced for pad holddown.
12570	ST.LV.A1.ST.SP.FH	First Stage Thrust Structure	For transferring load from First Stage Engine to tank structure.
12460	ST.LV.A1.ST.SF	Secondary Structure	
12487	ST.LV.A1.ST.SF.FX	First Stage Systems Tunnel Cover/Fairing	
12571	ST.LV.A1.ST.SF.FX	First Stage Inter-Stage Access Doors/Panels	
12572	ST.LV.A1.ST.SF.FX	First Stage Subsystem Mounting/Interconnecting Hardware	Plumbing line attachments, electrical cable attachments, LRU mountings.
12461	ST.LV.A1.MP	Main Propulsion	
12573	ST.LV.A1.MP.MD	Fill & Drain	First Stage filled from the ground at pad level. Vehicle fills Second Stage through the First Stage.
12589	ST.LV.A1.MP.MD.FU	First Stage RP Fill & Drain	Lines, valves and quantity gauges.
12590	ST.LV.A1.MP.MD.OX	First Stage LO2 Fill & Drain	Line, valves, and quantity gauges.
12574	ST.LV.A1.MP.MD	Propellant Storage	
12591	ST.LV.A1.MP.MD.FU	First Stage RP Tank	
12592	ST.LV.A1.MP.MD.OX	First Stage LO2 Tank	
12593	ST.LV.A1.MP.MD	Start Conditioning Systems	Not required for small pressure-fed stage.

ACT_Id_No	Pedigree	Name	Description
12594	ST.LV.A1.MP.MD.67	LOX/RP Start Conditioning Components	Not required for small pressure-fed stage.
12595	ST.LV.A1.MP.MD	Purge	Not required for small expendable pressure-fed stage.
12596	ST.LV.A1.MP.MD.67	First Stage Purge Components	Not required for small expendable pressure-fed stage.
12597	ST.LV.A1.MP.MD	Pressurization	
12599	ST.LV.A1.MP.MD.PE	First Stage RP Tank Pressurization Components	He storage tanks, plumbing lines and fittings, pressure regulators and valving, and heat exchanger.
12602	ST.LV.A1.MP.MD.PE	First Stage LO2 Tank Pressurization Components	He storage tanks, plumbing lines and fittings, pressure regulators and valving, and heat exchanger.
12603	ST.LV.A1.MP.MD	Tank Feed	
12604	ST.LV.A1.MP.MD.FU	First Stage RP Tank-Engine Feed Line Components	
12605	ST.LV.A1.MP.MD.OX	First Stage LO2 Tank-Engine Feed Line Components	
12606	ST.LV.A1.MP.MD	Propellant Inlet/Intake Management	Not required for this propulsion system concept (primarily for air-breathing main propulsion concepts).
12607	ST.LV.A1.MP.MD.67	Engine Intake/Inlet Components	Not required.
12608	ST.LV.A1.MP.MN	Thrust Generation/First Stage LOX/RP Engine	First Stage Thrust Generation
12609	ST.LV.A1.MP.MN.LQ	Combustion – First Stage LOX/RP Main Propellant Injector	One injector with two main prop interfaces.
12610	ST.LV.A1.MP.MN.LQ	Combustion – First Stage LOX/RP Main Combustion Chamber	Throat/chamber and pressure sensor.
12611	ST.LV.A1.MP.MN.LQ	Nozzle/Exhaust Gas management – First Stage LOX/RP Exhaust Nozzle	
12612	ST.LV.A1.MP.MN.LQ	Engine Start – First Stage LOX/RP Engine Ignition Assemblies/Components	
12613	ST.LV.A1.MP.MD	Propellant Management	
12614	ST.LV.A1.MP.MD.FU	First Stage RP Propellant system instrumentation	Sensors and instrumentation lines.
12615	ST.LV.A1.MP.MD.OX	First Stage LO2 Propellant system instrumentation	
12616	ST.LV.A1.MP.MD	Pogo Suppression	Not required for small, single engine, pressure-fed launcher.
12617	ST.LV.A1.MP.MD.67	First Stage Pogo Suppression Components	Not required.
12618	ST.LV.A1.MP.MD	Anti-Geyser Control	Not required for small, pressure-fed launcher.
12619	ST.LV.A1.MP.MD.67	First Stage Anti-Geyser Components	Not required.

ACT_Id_No	Pedigree	Name	Description
12620	ST.LV.A1.MP.MD	Propellant Acquisition and Settling	Not required for First Stage.
12621	ST.LV.A1.MP.MD.67	First Stage Propellant Acquisition and Settling Components	Not required for First Stage.
12622	ST.LV.A1.MP.MD	Propellant/Hardware Thermal Management	No subcooling of main propellant.
12623	ST.LV.A1.MP.MD.67	First Stage Densification Components	Not required.
12624	ST.LV.A1.MP.MD	Propellant System Control and Health Management	
12625	ST.LV.A1.MP.MD.67	First Stage LOX/RP Engine Controller/Sensors	Controller, harnesses, sensors.
12626	ST.LV.A1.MP.MT	Thrust Vector Control	
12627	ST.LV.A1.MP.MT.EP	First Stage Electric TVC Components	Pitch and Yaw actuators w/onboard controller/pwr switching, Dedicated battery source, harnesses. Actuators are either electromechanical actuator (EMA); or, electro-hydrastatic actuator (EHA), with self-contained motor-pumps). In either case (EMA/EHA), there are no hydraulic pumps distributing high-pressure fluid, and no fluid power APU energy/source.
12628	ST.LV.A1.MP.MD	Hardware contamination/flush for start/restart	Not required of this expendable stage.
12629	ST.LV.A1.MP.MD.67	First Stage Engine Purge/Restart Components	Not required.
12468	ST.LV.A1.PW	Electrical Power Generation, Control and Distribution	
12469	ST.LV.A1.PW.PD	Electrical Power Distribution	
12495	ST.LV.A1.PW.PD.35	First Stage Electrical Power Cabling	Ignition power is provided from ground or from upstage source carried through the wiring tunnel covers.
12630	ST.LV.A1.PW.PD.E1	First Stage Remote Power Controllers and Other Switch Gear	
12631	ST.LV.A1.PW.ES	Energy/Power Source	
12632	ST.LV.A1.PW.ES.BT	First Stage TVC System Batteries	Dual.
12633	ST.LV.A1.PW.ES.BT	First Stage Dedicated FTS Battery	
12470	ST.LV.A1.TP	Thermal Control	
12471	ST.LV.A1.TP.PN	Passive Thermal Protection	
12496	ST.LV.A1.TP.PN.BL	First Thermal Blanket TPS Components	(Only for pad launch option.)
12636	ST.LV.A1.TP.PN	Thermal Insulation	
12637	ST.LV.A1.TP.PN.FO	First Stage LOX Tank Insulation	

ACT_Id_No	Pedigree	Name	Description
12474	ST.LV.A1.CC	Flight Stabilization and Control	
12634	ST.LV.A1.CC.CG	Roll Control	
12635	ST.LV.A1.CC.CG.59	First Stage Roll Control System Assemblies/Components	Method TBD.
12476	ST.LV.A1.CC	Command and Data Management	
12477	ST.LV.A1.CC.CD	Command and Data Distribution	
12500	ST.LV.A1.CC.CD.51	First Stage Command and Data Cabling/Wiring	
12478	ST.LV.A1.CC	Flight Termination	
12479	ST.LV.A1.CC.CR	Destruct Systems	Engine shutdown method assumed.
12501	ST.LV.A1.CC.CR.RC	First Stage Destruct Command Electronics	
12502	ST.LV.A1.CC.CR.55	First Stage Destruct Equipment	May not be needed for engine shutdown approach.
12480	ST.LV.A1.ME	Stage/Element Separation	
12481	ST.LV.A1.ME.SX	Non-Ordnance Stage Separation	
12503	ST.LV.A1.ME.SX.ME	First Stage Mechanical Separation Components	Spring sets.
12482	ST.LV.A1.ME.SX	Ordnance Stage Separation	
12504	ST.LV.A1.ME.SX.OR	First Stage Ordnance Separation Components	Pyrotechnical devices requiring special keep-out zone, work stoppage operations, dedicated ordnance storage facilities, and ground equipment.
12483	ST.LV.A1.RL	Launch/Takeoff and Landing Support	
12484	ST.LV.A1.RL.RG	Launch Support	
12505	ST.LV.A1.RL.RG.105	First Stage Pad Holddown Structural/Mechanical Interface Components	
12722	ST.LV.A1	Second Stage – LOX/RP	
12723	ST.LV.A1.ST	Body Structure	
12724	ST.LV.A1.ST.SP	Primary Load-Bearing Structure	
12762	ST.LV.A1.ST.SP.FH	Second Stage Intertank Structure	Provides primary load path between main propellant tanks.
12764	ST.LV.A1.ST.SP.FH	Second Stage Thrust Structure	For transferring load from Second Stage Engine to tank structure.
12725	ST.LV.A1.ST.SF	Secondary Structure	
12765	ST.LV.A1.ST.SF.FX	Second Stage Systems Tunnel Cover/Fairing	
12767	ST.LV.A1.ST.SF.FX	Second Stage Subsystem Mounting/Interconnecting Hardware	Plumbing line attachments, electrical cable attachments, LRU mountings.
12726	ST.LV.A1.MP	Main Propulsion	

ACT_Id_No	Pedigree	Name	Description
12727	ST.LV.A1.MP.MD	Fill & Drain	Second Stage fills and drains through the First Stage.
12768	ST.LV.A1.MP.MD.FU	Second Stage RP Fill & Drain	Filled from connection to First Stage.
12769	ST.LV.A1.MP.MD.OX	Second Stage LO2 Fill & Drain	Line, valves, and quantity gauges.
12728	ST.LV.A1.MP.MD	Propellant Storage	
12770	ST.LV.A1.MP.MD.FU	Second Stage RP Tank	
12771	ST.LV.A1.MP.MD.OX	Second Stage LO2 Tank	
12729	ST.LV.A1.MP.MD	Start Conditioning Systems	Not required for small pressure-fed stage.
12772	ST.LV.A1.MP.MD.67	LOX/RP Start Conditioning Components	Not required for small pressure-fed stage.
12730	ST.LV.A1.MP.MD	Purge	Not required for small expendable pressure-fed stage.
12773	ST.LV.A1.MP.MD.67	First Stage Purge Components	Not required for small expendable pressure-fed stage.
12731	ST.LV.A1.MP.MD	Pressurization	
12774	ST.LV.A1.MP.MD.PE	Second Stage RP Tank Pressurization Components	He storage tanks, plumbing lines and fittings, pressure regulators and valving, and heat exchanger.
12775	ST.LV.A1.MP.MD.PE	Second Stage LO2 Tank Pressurization Components	He storage tanks, plumbing lines and fittings, pressure regulators and valving, and heat exchanger.
12732	ST.LV.A1.MP.MD	Tank Feed	
12776	ST.LV.A1.MP.MD.FU	Second Stage RP Tank-Engine Feed Line Components	
12777	ST.LV.A1.MP.MD.OX	Second Stage LO2 Tank-Engine Feed Line Components	
12733	ST.LV.A1.MP.MD	Propellant Inlet/Intake Management	Not required for this propulsion system concept (primarily for air-breathing main propulsion concepts).
12778	ST.LV.A1.MP.MD.67	Engine Intake/Inlet Components	Not required.
12734	ST.LV.A1.MP.MN	Thrust Generation/Second Stage LOX/RP Engine	Second Stage Thrust Generation
12779	ST.LV.A1.MP.MN.LQ	Combustion – Second Stage LOX/RP Main Propellant Injector	One injector with two main prop interfaces.
12780	ST.LV.A1.MP.MN.LQ	Combustion – Second Stage LOX/RP Main Combustion Chamber	Throat/chamber and pressure sensor.
12781	ST.LV.A1.MP.MN.LQ	Nozzle/Exhaust Gas management – Second Stage LOX/RP Exhaust Nozzle	
12782	ST.LV.A1.MP.MN.LQ	Engine Start – Second Stage LOX/RP Engine Ignition Assemblies/Components	
12735	ST.LV.A1.MP.MD	Propellant Management	
12783	ST.LV.A1.MP.MD.FU	Second Stage RP Propellant system instrumentation	Sensors and instrumentation lines.
12784	ST.LV.A1.MP.MD.OX	Second Stage LO2 Propellant system instrumentation	

ACT_Id_No	Pedigree	Name	Description
12736	ST.LV.A1.MP.MD	Pogo Suppression	Not required for small, single engine, pressure-fed launcher.
12785	ST.LV.A1.MP.MD.67	First Stage Pogo Suppression Components	Not required.
12737	ST.LV.A1.MP.MD	Anti-Geyser Control	Not required for small, pressure-fed launcher.
12786	ST.LV.A1.MP.MD.67	Second Stage Anti-Geyser Components	Not required.
12738	ST.LV.A1.MP.MD	Propellant Acquisition and Settling	Not required for First Stage.
12787	ST.LV.A1.MP.MD.67	Second Stage Propellant Acquisition and Settling Components	Not required for First Stage.
12739	ST.LV.A1.MP.MD	Propellant/Hardware Thermal Management	No subcooling of main propellant.
12788	ST.LV.A1.MP.MD.67	Second Stage Densification Components	Not required.
12740	ST.LV.A1.MP.MD	Propellant System Control and Health Management	
12789	ST.LV.A1.MP.MD.67	Second Stage LOX/RP Engine Controller/Sensors	Controller, harnesses, sensors.
12741	ST.LV.A1.MP.MT	Thrust Vector Control	
12790	ST.LV.A1.MP.MT.EP	Second Stage Electric TVC Components	Pitch and Yaw actuators w/onboard controller/pwr switching, Dedicated Battery source, harnesses. Actuators are either electromechanical actuator (EMA); or, electro-hydrastatic actuator (EHA), with self-contained motor-pumps). In either case (EMA/EHA), there are no hydraulic pumps distributing high pressure fluid, and no fluid power APU energy/source.
12742	ST.LV.A1.MP.MD	Hardware contamination/flush for start/restart	Not required of this expendable stage.
12791	ST.LV.A1.MP.MD.67	Second Stage Engine Purge/Restart Components	Not required.
12743	ST.LV.A1.PW	Electrical Power Generation, Control and Distribution	
12744	ST.LV.A1.PW.PD	Electrical Power Distribution	
12792	ST.LV.A1.PW.PD.35	Second Stage Electrical Power Cabling	Ignition power is provided from ground or from upstage source carried through the wiring tunnel covers.
12793	ST.LV.A1.PW.PD.E1	Second Stage Remote Power Controllers and Other Switch Gear	
12745	ST.LV.A1.PW.ES	Energy/Power Source	
12794	ST.LV.A1.PW.ES.BT	Second Stage TVC System and Stage Supply Bus Batteries	Triple.
12795	ST.LV.A1.PW.ES.BT	Second Stage Dedicated FTS Battery	

ACT_Id_No	Pedigree	Name	Description
12746	ST.LV.A1.TP	Thermal Control	
12747	ST.LV.A1.TP.PN	Passive Thermal Protection	
12796	ST.LV.A1.TP.PN.BL	Second Stage Thermal Blanket TPS Components	(Only for pad launch option.)
12748	ST.LV.A1.TP.PN	Thermal Insulation	
12797	ST.LV.A1.TP.PN.FO	Second Stage LOX Tank Insulation	
12751	ST.LV.A1.CC	Flight Stabilization and Control	
12752	ST.LV.A1.CC.CG	Roll Control	
12799	ST.LV.A1.CC.CG.59	Second Stage Roll Control System Assemblies/Components	Method TBD.
12753	ST.LV.A1.CC	Command and Data Management	
12754	ST.LV.A1.CC.CD	Command and Data Distribution	
12800	ST.LV.A1.CC.CD.51	Second Stage Command and Data Cabling/Wiring	
12806	ST.LV.A1.CC.CD.FD	Vehicle Systems Interface Components	
12807	ST.LV.A1.CC.CD.GC	Ground Interface Components	Trickle charge, ignition, hardwire telemetry, etc.
12808	ST.LV.A1.CC.CD.CM	Vehicle Central Processing & Storage	
12809	ST.LV.A1.CC.CT	Communication & Tracking	
12810	ST.LV.A1.CC.CT.CB	C-Band Tracking Transponder and Antennas – Radar Tracking	
12811	ST.LV.A1.CC.CT.SB	S-Band Telemetry Transmitter and Antennas	Range-required telemetry and customer-required telemetry in the same data stream.
12812	ST.LV.A1.CC.CT.UH	UHF FTS Receiver and Antennas – FTS Destruct Command	
12813	ST.LV.A1.CC.CT.53	GPS Receiver Antennas – Navigation	
12755	ST.LV.A1.CC	Flight Termination	
12756	ST.LV.A1.CC.CR	Destruct Systems	Engine shutdown method assumed.
12801	ST.LV.A1.CC.CR.RC	Second Stage Destruct Command Electronics	
12802	ST.LV.A1.CC.CR.55	Second Stage Destruct Equipment	May not be needed for engine shutdown approach.
12757	ST.LV.A1.ME	Stage/Element Separation	
12758	ST.LV.A1.ME.SX	Non-Ordnance Stage Separation	
12803	ST.LV.A1.ME.SX.ME	First Stage Mechanical Separation Components	Spring sets.
12759	ST.LV.A1.ME.SX	Ordnance Stage Separation	

ACT_Id_No	Pedigree	Name	Description
12804	ST.LV.A1.ME.SX.OR	Second Stage-Payload Fairing Ordnance Separation Components	Pyrotechnical devices requiring special keep-out zone, work stoppage operations, dedicated ordnance storage facilities, and ground equipment.
12817	ST.LV.A3	Payload Fairing	
12818	ST.LV.A3.ST	Payload Fairing Panels	
12819	ST.LV.A3.ST.SF	Payload Fairing Systems	
12820	ST.LV.A3.ST.SF.SP	Payload Fairing Assemblies/Components	

APPENDIX D. SAMPLE FOUR-STAGE ALL-SOLID NANOLAUNCHER, NL001, BASELINE SYSTEM DEFINITION SHEET

(created w/SBS Tool in Phase II)

SYS CODE	ARCH	TYPE	SEGMENT	ELEMENT	SUBSYSTEM	COMPONENT/ASSEMBLY	MASS	SYS_CMPLX	TOTAL_IF	NORM_IF	TOXIC_IF	ORDN_IF	CONF_SP_IF	REUSE_INDX
1.1.1.01.01.01	NANOLAUNCHER PHASE II BASELINE	FOUR STAGE/ALL-SOLID BASELINE	NL001 VEHICLE	NL001_STAGE 1	STRUCTURE	AFT SKIRT STRUCTURE (REINFORCED FOR STABILIZER FINS)	0	1	5	5	0	0	0	0
1.1.1.01.01.02	NANOLAUNCHER PHASE II BASELINE	FOUR STAGE/ALL-SOLID BASELINE	NL001 VEHICLE	NL001_STAGE 1	STRUCTURE	SYSTEMS TUNNEL COVER/FAIRING	0	1	5	5	0	0	0	0
1.1.1.01.01.03	NANOLAUNCHER PHASE II BASELINE	FOUR STAGE/ALL-SOLID BASELINE	NL001 VEHICLE	NL001_STAGE 1	STRUCTURE	FWD INTERSTAGE STRUCTURE	0	1	5	5	0	0	0	0
1.1.1.01.01.04	NANOLAUNCHER PHASE II BASELINE	FOUR STAGE/ALL-SOLID BASELINE	NL001 VEHICLE	NL001_STAGE 1	STRUCTURE	SPIN-UP SYSTEM ACCESS DOORS/PANELS (LOCATED ON FWD INTERSTAGE)	0	1	5	5	0	0	0	0
1.1.1.01.02.01	NANOLAUNCHER PHASE II BASELINE	FOUR STAGE/ALL-SOLID BASELINE	NL001 VEHICLE	NL001_STAGE 1	STABILIZATION	FIXED STABILIZER FINS (3 OR 4)	0	1	4	4	0	0	0	0
1.1.1.01.02.02	NANOLAUNCHER PHASE II BASELINE	FOUR STAGE/ALL-SOLID BASELINE	NL001 VEHICLE	NL001_STAGE 1	STABILIZATION	SPIN-UP MOTORS W/MOUNTINGS (LOCATED IN FWD INTERSTAGE)	0	1	4	0	0	4	0	0
1.1.1.01.03.01	NANOLAUNCHER PHASE II BASELINE	FOUR STAGE/ALL-SOLID BASELINE	NL001 VEHICLE	NL001_STAGE 1	SOLID ROCKET MOTOR (STAR 31)	SOLID ROCKET MOTOR CASE STRUCTURE	0	1	5	4	0	1	0	0
1.1.1.01.03.02	NANOLAUNCHER PHASE II BASELINE	FOUR STAGE/ALL-SOLID BASELINE	NL001 VEHICLE	NL001_STAGE 1	SOLID ROCKET MOTOR (STAR 31)	SOLID ROCKET MOTOR CASE INSULATION	0	1	5	4	0	1	0	0
1.1.1.01.03.03	NANOLAUNCHER PHASE II BASELINE	FOUR STAGE/ALL-SOLID BASELINE	NL001 VEHICLE	NL001_STAGE 1	SOLID ROCKET MOTOR (STAR 31)	SOLID PROPELLANT (EXPENDED)	0	1	1	0	0	1	0	0
1.1.1.01.03.04	NANOLAUNCHER PHASE II BASELINE	FOUR STAGE/ALL-SOLID BASELINE	NL001 VEHICLE	NL001_STAGE 1	SOLID ROCKET MOTOR (STAR 31)	SOLID PROPELLANT (RESIDUAL)	0	0	0	0	0	0	0	0
1.1.1.01.03.05	NANOLAUNCHER PHASE II BASELINE	FOUR STAGE/ALL-SOLID BASELINE	NL001 VEHICLE	NL001_STAGE 1	SOLID ROCKET MOTOR (STAR 31)	EXHAUST NOZZLE	0	1	1	1	0	0	0	0
1.1.1.01.03.06	NANOLAUNCHER PHASE II BASELINE	FOUR STAGE/ALL-SOLID BASELINE	NL001 VEHICLE	NL001_STAGE 1	SOLID ROCKET MOTOR (STAR 31)	SOLID ROCKET MOTOR MAIN CHAMBER IGNITER SYSTEM COMPONENTS	0	2	4	2	0	2	0	0
1.1.1.01.03.07	NANOLAUNCHER PHASE II BASELINE	FOUR STAGE/ALL-SOLID BASELINE	NL001 VEHICLE	NL001_STAGE 1	SOLID ROCKET MOTOR (STAR 31)	SENSORS (CHAMBER PRESSURE)	0	1	11	10	0	1	0	0
1.1.1.01.04.01	NANOLAUNCHER PHASE II BASELINE	FOUR STAGE/ALL-SOLID BASELINE	NL001 VEHICLE	NL001_STAGE 1	ELECTRICAL POWER DISTRIBUTION	POWER CABLING	0	1	4	2	0	2	0	0
1.1.1.01.05.01	NANOLAUNCHER PHASE II BASELINE	FOUR STAGE/ALL-SOLID BASELINE	NL001 VEHICLE	NL001_STAGE 1	THERMAL PROTECTION	THERMAL BLANKET TPS COMPONENTS (ONLY FOR LAUNCH PAD OPTION)	0	0	0	0	0	0	0	0
1.1.1.01.06.01	NANOLAUNCHER PHASE II BASELINE	FOUR STAGE/ALL-SOLID BASELINE	NL001 VEHICLE	NL001_STAGE 1	VENT	OUTLETS AND VENTS (ON FWD INTERSTAGE)	0	1	2	2	0	0	0	0
1.1.1.01.07.01	NANOLAUNCHER PHASE II BASELINE	FOUR STAGE/ALL-SOLID BASELINE	NL001 VEHICLE	NL001_STAGE 1	COMMAND & CONTROL	CABLING AND WIRING	0	1	2	2	0	0	0	0
1.1.1.01.08.01	NANOLAUNCHER PHASE II BASELINE	FOUR STAGE/ALL-SOLID BASELINE	NL001 VEHICLE	NL001_STAGE 1	SEPARATION	MECHANICAL SEPARATION COMPONENTS (E.G., SPRING SETS)	0	2	2	2	0	0	0	0
1.1.1.01.08.02	NANOLAUNCHER PHASE II BASELINE	FOUR STAGE/ALL-SOLID BASELINE	NL001 VEHICLE	NL001_STAGE 1	SEPARATION	ORDNANCE (IF REQUIRED)	0	0	0	0	0	0	0	0
1.1.1.01.09.01	NANOLAUNCHER PHASE II BASELINE	FOUR STAGE/ALL-SOLID BASELINE	NL001 VEHICLE	NL001_STAGE 1	RAIL (FLT HALF)	LAUNCH RAIL INTERFACE SRUCTURAL/MECHANICAL EQUIPMENT (FLT HALF)	0	1	1	1	0	0	0	0
1.1.1.02.01.01	NANOLAUNCHER PHASE II BASELINE	FOUR STAGE/ALL-SOLID BASELINE	NL001 VEHICLE	NL001_STAGE 2	STRUCTURE	AFT INTERSTAGE STRUCTURE (REINFORCED FOR STABILIZER FINS)	0	1	5	5	0	0	0	0
1.1.1.02.01.02	NANOLAUNCHER PHASE II BASELINE	FOUR STAGE/ALL-SOLID BASELINE	NL001 VEHICLE	NL001_STAGE 2	STRUCTURE	SYSTEMS TUNNEL COVER/FAIRING	0	1	2	2	0	0	0	0
1.1.1.02.01.03	NANOLAUNCHER PHASE II BASELINE	FOUR STAGE/ALL-SOLID BASELINE	NL001 VEHICLE	NL001_STAGE 2	STRUCTURE	FWD INTERSTAGE STRUCTURE	0	1	2	2	0	0	0	0
1.1.1.02.01.04	NANOLAUNCHER PHASE II BASELINE	FOUR STAGE/ALL-SOLID BASELINE	NL001 VEHICLE	NL001_STAGE 2	STRUCTURE	FWD INTERSTAGE ACCESS PANELS	0	1	1	1	0	0	0	0
1.1.1.02.02.01	NANOLAUNCHER PHASE II BASELINE	FOUR STAGE/ALL-SOLID BASELINE	NL001 VEHICLE	NL001_STAGE 2	STABILIZATION	FIXED STABILIZER FINS	0	1	1	1	0	0	0	0
1.1.1.02.03.01	NANOLAUNCHER PHASE II BASELINE	FOUR STAGE/ALL-SOLID BASELINE	NL001 VEHICLE	NL001_STAGE 2	SOLID ROCKET MOTOR (STAR 20B-LIKE)	SOLID ROCKET MOTOR CASE STRUCTURE	0	1	5	4	0	1	0	0
1.1.1.02.03.02	NANOLAUNCHER PHASE II BASELINE	FOUR STAGE/ALL-SOLID BASELINE	NL001 VEHICLE	NL001_STAGE 2	SOLID ROCKET MOTOR (STAR 20B-LIKE)	SOLID ROCKET MOTOR CASE INSULATION	0	1	2	1	0	1	0	0
1.1.1.02.03.03	NANOLAUNCHER PHASE II BASELINE	FOUR STAGE/ALL-SOLID BASELINE	NL001 VEHICLE	NL001_STAGE 2	SOLID ROCKET MOTOR (STAR 20B-LIKE)	SOLID PROPELLANT (EXPENDED)	0	1	1	0	0	1	0	0
1.1.1.02.03.04	NANOLAUNCHER PHASE II BASELINE	FOUR STAGE/ALL-SOLID BASELINE	NL001 VEHICLE	NL001_STAGE 2	SOLID ROCKET MOTOR (STAR 20B-LIKE)	SOLID PROPELLANT (RESIDUAL)	0	0	0	0	0	0	0	0
1.1.1.02.03.05	NANOLAUNCHER PHASE II BASELINE	FOUR STAGE/ALL-SOLID BASELINE	NL001 VEHICLE	NL001_STAGE 2	SOLID ROCKET MOTOR (STAR 20B-LIKE)	EXHAUST NOZZLE	0	1	1	1	0	0	0	0
1.1.1.02.03.06	NANOLAUNCHER PHASE II BASELINE	FOUR STAGE/ALL-SOLID BASELINE	NL001 VEHICLE	NL001_STAGE 2	SOLID ROCKET MOTOR (STAR 20B-LIKE)	SOLID ROCKET MOTOR MAIN CHAMBER IGNITER SYSTEM COMPONENTS	0	2	4	2	0	2	0	0
1.1.1.02.03.07	NANOLAUNCHER PHASE II BASELINE	FOUR STAGE/ALL-SOLID BASELINE	NL001 VEHICLE	NL001_STAGE 2	SOLID ROCKET MOTOR (STAR 20B-LIKE)	SENSORS (CHAMBER PRESSURE)	0	1	11	10	0	1	0	0
1.1.1.02.04.01	NANOLAUNCHER PHASE II BASELINE	FOUR STAGE/ALL-SOLID BASELINE	NL001 VEHICLE	NL001_STAGE 2	ELECTRICAL POWER DISTRIBUTION	POWER CABLING	0	1	4	2	0	2	0	0
1.1.1.02.05.01	NANOLAUNCHER PHASE II BASELINE	FOUR STAGE/ALL-SOLID BASELINE	NL001 VEHICLE	NL001_STAGE 2	VENT	OUTLETS AND VENTS (ON FWD INTERSTAGE)	0	1	2	2	0	0	0	0
1.1.1.02.06.01	NANOLAUNCHER PHASE II BASELINE	FOUR STAGE/ALL-SOLID BASELINE	NL001 VEHICLE	NL001_STAGE 2	COMMAND & CONTROL	CABLING AND WIRING	0	1	2	2	0	0	0	0
1.1.1.02.07.01	NANOLAUNCHER PHASE II BASELINE	FOUR STAGE/ALL-SOLID BASELINE	NL001 VEHICLE	NL001_STAGE 2	SEPARATION	MECHANICAL SEPARATION COMPONENTS (E.G., SPRING SETS)	0	1	2	2	0	0	0	0
1.1.1.02.08.01	NANOLAUNCHER PHASE II BASELINE	FOUR STAGE/ALL-SOLID BASELINE	NL001 VEHICLE	NL001_STAGE 2	RAIL (FLT HALF)	LAUNCH RAIL INTERFACE STRUCTURAL/MECHANICAL EQUIPMENT (FLIGHT HALF)	0	1	1	1	0	0	0	0
1.1.1.03.01.01	NANOLAUNCHER PHASE II BASELINE	FOUR STAGE/ALL-SOLID BASELINE	NL001 VEHICLE	NL001_STAGE 3	STRUCTURE	AFT INTERSTAGE STRUCTURE (REINFORCED FOR STABILIZER FINS)	0	1	5	5	0	0	0	0
1.1.1.03.01.02	NANOLAUNCHER PHASE II BASELINE	FOUR STAGE/ALL-SOLID BASELINE	NL001 VEHICLE	NL001_STAGE 3	STRUCTURE	SYSTEMS TUNNEL COVER/FAIRING	0	1	2	2	0	0	0	0
1.1.1.03.01.03	NANOLAUNCHER PHASE II BASELINE	FOUR STAGE/ALL-SOLID BASELINE	NL001 VEHICLE	NL001_STAGE 3	STRUCTURE	FWD INTERSTAGE STRUCTURE	0	1	3	2	0	1	0	0
1.1.1.03.01.04	NANOLAUNCHER PHASE II BASELINE	FOUR STAGE/ALL-SOLID BASELINE	NL001 VEHICLE	NL001_STAGE 3	STRUCTURE	FWD INTERSTAGE ACCESS PANELS	0	1	1	1	0	0	0	0
1.1.1.03.01.05	NANOLAUNCHER PHASE II BASELINE	FOUR STAGE/ALL-SOLID BASELINE	NL001 VEHICLE	NL001_STAGE 3	STRUCTURE	AFT INTERSTAGE ACCESS PANELS	0	1	1	1	0	0	0	0
1.1.1.03.01.06	NANOLAUNCHER PHASE II BASELINE	FOUR STAGE/ALL-SOLID BASELINE	NL001 VEHICLE	NL001_STAGE 3	STRUCTURE	THIRD/FOURTH STAGE ADAPTER STRUCTURE	0	1	4	4	0	0	0	0
1.1.1.03.02.01	NANOLAUNCHER PHASE II BASELINE	FOUR STAGE/ALL-SOLID BASELINE	NL001 VEHICLE	NL001_STAGE 3	STABILIZATION	DE-SPIN/YO-YO COMPONENTS/ASSEMBLY	0	2	6	5	0	1	0	0
1.1.1.03.03.01	NANOLAUNCHER PHASE II BASELINE	FOUR STAGE/ALL-SOLID BASELINE	NL001 VEHICLE	NL001_STAGE 3	SOLID ROCKET MOTOR (STAR 15G-LIKE)	SOLID ROCKET MOTOR CASE STRUCTURE	0	1	5	4	0	1	0	0
1.1.1.03.03.02	NANOLAUNCHER PHASE II BASELINE	FOUR STAGE/ALL-SOLID BASELINE	NL001 VEHICLE	NL001_STAGE 3	SOLID ROCKET MOTOR (STAR 15G-LIKE)	SOLID ROCKET MOTOR CASE INSULATION	0	1	2	1	0	1	0	0
1.1.1.03.03.03	NANOLAUNCHER PHASE II BASELINE	FOUR STAGE/ALL-SOLID BASELINE	NL001 VEHICLE	NL001_STAGE 3	SOLID ROCKET MOTOR (STAR 15G-LIKE)	SOLID PROPELLANT (EXPENDED)	0	1	1	0	0	1	0	0
1.1.1.03.03.04	NANOLAUNCHER PHASE II BASELINE	FOUR STAGE/ALL-SOLID BASELINE	NL001 VEHICLE	NL001_STAGE 3	SOLID ROCKET MOTOR (STAR 15G-LIKE)	SOLID PROPELLANT (RESIDUAL)	0	0	0	0	0	0	0	0
1.1.1.03.03.05	NANOLAUNCHER PHASE II BASELINE	FOUR STAGE/ALL-SOLID BASELINE	NL001 VEHICLE	NL001_STAGE 3	SOLID ROCKET MOTOR (STAR 15G-LIKE)	EXHAUST NOZZLE	0	1	1	1	0	0	0	0
1.1.1.03.03.06	NANOLAUNCHER PHASE II BASELINE	FOUR STAGE/ALL-SOLID BASELINE	NL001 VEHICLE	NL001_STAGE 3	SOLID ROCKET MOTOR (STAR 15G-LIKE)	SOLID ROCKET MOTOR MAIN CHAMBER IGNITER SYSTEM COMPONENTS	0	2	4	2	0	2	0	0
1.1.1.03.03.07	NANOLAUNCHER PHASE II BASELINE	FOUR STAGE/ALL-SOLID BASELINE	NL001 VEHICLE	NL001_STAGE 3	SOLID ROCKET MOTOR (STAR 15G-LIKE)	SENSORS (CHAMBER PRESSURE)	0	1	11	10	0	1	0	0
1.1.1.03.04.01	NANOLAUNCHER PHASE II BASELINE	FOUR STAGE/ALL-SOLID BASELINE	NL001 VEHICLE	NL001_STAGE 3	ELECTRICAL POWER	AVIONICS DC BATTERY	0	1	1	1	0	0	0	0
1.1.1.03.04.02	NANOLAUNCHER PHASE II BASELINE	FOUR STAGE/ALL-SOLID BASELINE	NL001 VEHICLE	NL001_STAGE 3	ELECTRICAL POWER	DC POWER DISTRIBUTION UNIT	0	1	7	7	0	0	0	0
1.1.1.03.04.03	NANOLAUNCHER PHASE II BASELINE	FOUR STAGE/ALL-SOLID BASELINE	NL001 VEHICLE	NL001_STAGE 3	ELECTRICAL POWER	ELECTRIC POWER HARNESSES, CABLES, WIRING	0	1	6	5	0	1	0	0
1.1.1.03.05.01	NANOLAUNCHER PHASE II BASELINE	FOUR STAGE/ALL-SOLID BASELINE	NL001 VEHICLE	NL001_STAGE 3	VENT	OUTLETS & VENTS	0	1	2	2	0	0	0	0
1.1.1.03.06.01	NANOLAUNCHER PHASE II BASELINE	FOUR STAGE/ALL-SOLID BASELINE	NL001 VEHICLE	NL001_STAGE 3	COMMAND & CONTROL	SIGNAL HARNESSES, CABLES, WIRING	0	1	13	12	0	1	0	0
1.1.1.03.07.01	NANOLAUNCHER PHASE II BASELINE	FOUR STAGE/ALL-SOLID BASELINE	NL001 VEHICLE	NL001_STAGE 3	COMMUNICATIONS	TM ENCODER UNIT	0	1	3	3	0	0	0	0
1.1.1.03.07.05	NANOLAUNCHER PHASE II BASELINE	FOUR STAGE/ALL-SOLID BASELINE	NL001 VEHICLE	NL001_STAGE 3	COMMUNICATIONS	S-BAND ANTENNA 1	0	1	1	1	0	0	0	0
1.1.1.03.07.05	NANOLAUNCHER PHASE II BASELINE	FOUR STAGE/ALL-SOLID BASELINE	NL001 VEHICLE	NL001_STAGE 3	COMMUNICATIONS	C-BAND RADAR BEACON ANTENNA 1	0	1	1	1	0	0	0	0
1.1.1.03.07.06	NANOLAUNCHER PHASE II BASELINE	FOUR STAGE/ALL-SOLID BASELINE	NL001 VEHICLE	NL001_STAGE 3	COMMUNICATIONS	S-BAND ANTENNA 2	0	1	1	1	0	0	0	0
1.1.1.03.07.06	NANOLAUNCHER PHASE II BASELINE	FOUR STAGE/ALL-SOLID BASELINE	NL001 VEHICLE	NL001_STAGE 3	COMMUNICATIONS	C-BAND RADAR BEACON ANTENNA 2	0	1	1	1	0	0	0	0
1.1.1.03.07.07	NANOLAUNCHER PHASE II BASELINE	FOUR STAGE/ALL-SOLID BASELINE	NL001 VEHICLE	NL001_STAGE 3	COMMUNICATIONS	S-BAND TRANSPONDER	0	1	5	5	0	0	0	0
1.1.1.03.07.07	NANOLAUNCHER PHASE II BASELINE	FOUR STAGE/ALL-SOLID BASELINE	NL001 VEHICLE	NL001_STAGE 3	COMMUNICATIONS	C-BAND RADAR BEACON UNIT	0	1	3	3	0	0	0	0
1.1.1.03.08.02	NANOLAUNCHER PHASE II BASELINE	FOUR STAGE/ALL-SOLID BASELINE	NL001 VEHICLE	NL001_STAGE 3	NAVIGATION	GPS/L-BAND ANTENNA 1	0	1	1	1	0	0	0	0
1.1.1.03.08.02	NANOLAUNCHER PHASE II BASELINE	FOUR STAGE/ALL-SOLID BASELINE	NL001 VEHICLE	NL001_STAGE 3	NAVIGATION	ATTITUDE CONTROL DRIVER/SIGNAL CONDITIONER	0	1	12	12	0	0	0	0
1.1.1.03.08.03	NANOLAUNCHER PHASE II BASELINE	FOUR STAGE/ALL-SOLID BASELINE	NL001 VEHICLE	NL001_STAGE 3	NAVIGATION	GPS/L-BAND ANTENNA 2	0	1	1	1	0	0	0	0
1.1.1.03.08.04	NANOLAUNCHER PHASE II BASELINE	FOUR STAGE/ALL-SOLID BASELINE	NL001 VEHICLE	NL001_STAGE 3	NAVIGATION	GPS ELECTRONICS (LNA/COMB FILTER/RECEIVER)	0	1	5	5	0	0	0	0
1.1.1.03.08.05	NANOLAUNCHER PHASE II BASELINE	FOUR STAGE/ALL-SOLID BASELINE	NL001 VEHICLE	NL001_STAGE 3	NAVIGATION	INS UNIT	0	1	3	3	0	0	0	0
1.1.1.03.09.01	NANOLAUNCHER PHASE II BASELINE	FOUR STAGE/ALL-SOLID BASELINE	NL001 VEHICLE	NL001_STAGE 3	FLIGHT TERMINATION	UHF FLT TERMINATION ANTENNA 1	0	1	1	1	0	0	0	0
1.1.1.03.09.02	NANOLAUNCHER PHASE II BASELINE	FOUR STAGE/ALL-SOLID BASELINE	NL001 VEHICLE	NL001_STAGE 3	FLIGHT TERMINATION	UHF FLT TERMINATION ANTENNA 2	0	1	1	1	0	0	0	0
1.1.1.03.09.03	NANOLAUNCHER PHASE II BASELINE	FOUR STAGE/ALL-SOLID BASELINE	NL001 VEHICLE	NL001_STAGE 3	FLIGHT TERMINATION	FLT TERMINATION RECEIVER 1	0	1	4	3	0	1	0	0
1.1.1.03.09.04	NANOLAUNCHER PHASE II BASELINE	FOUR STAGE/ALL-SOLID BASELINE	NL001 VEHICLE	NL001_STAGE 3	FLIGHT TERMINATION	FLT TERMINATION RECEIVER 2	0	1	4	3	0	1	0	0
1.1.1.03.09.05	NANOLAUNCHER PHASE II BASELINE	FOUR STAGE/ALL-SOLID BASELINE	NL001 VEHICLE	NL001_STAGE 3	FLIGHT TERMINATION	FLT TERMINATION BATTERY 1	0	1	4	2	0	2	0	0
1.1.1.03.09.06	NANOLAUNCHER PHASE II BASELINE	FOUR STAGE/ALL-SOLID BASELINE	NL001 VEHICLE	NL001_STAGE 3	FLIGHT TERMINATION	FLT TERMINATION BATTERY 2	0	1	4	2	0	2	0	0
1.1.1.03.09.07	NANOLAUNCHER PHASE II BASELINE	FOUR STAGE/ALL-SOLID BASELINE	NL001 VEHICLE	NL001_STAGE 3	FLIGHT TERMINATION	FLT TERMINATION SYSTEM ORDNANCE DRIVER UNIT	0	1	6	0	0	6	0	0
1.1.1.03.09.08	NANOLAUNCHER PHASE II BASELINE	FOUR STAGE/ALL-SOLID BASELINE	NL001 VEHICLE	NL001_STAGE 3	FLIGHT TERMINATION	DESTRUCT ORDNANCE (THRID AND FOURTH STG)	0	2	2	0	0	2	0	0
1.1.1.03.10.01	NANOLAUNCHER PHASE II BASELINE	FOUR STAGE/ALL-SOLID BASELINE	NL001 VEHICLE	NL001_STAGE 3	SEPARATION	MECHANICAL SEPARATION COMPONENTS/ASSEMBLY	0	2	2	2	0	0	0	0
1.1.1.04.01.01	NANOLAUNCHER PHASE II BASELINE	FOUR STAGE/ALL-SOLID BASELINE	NL001 VEHICLE	NL001_STAGE 4	STRUCTURE	ADAPTER RING STRUCTURE	0	2	3	3	0	0	0	0
1.1.1.04.02.01	NANOLAUNCHER PHASE II BASELINE	FOUR STAGE/ALL-SOLID BASELINE	NL001 VEHICLE	NL001_STAGE 4	ATTITUDE CONTROL	REACTION CONTROL JETS/MODULES	0	1	24	24	0	0	0	0
1.1.1.04.02.02	NANOLAUNCHER PHASE II BASELINE	FOUR STAGE/ALL-SOLID BASELINE	NL001 VEHICLE	NL001_STAGE 4	ATTITUDE CONTROL	REACTION CONTROL PROPELLANT STORAGE AND DISTRIBUTION	0	1	14	14	0	0	0	0
1.1.1.04.03.01	NANOLAUNCHER PHASE II BASELINE	FOUR STAGE/ALL-SOLID BASELINE	NL001 VEHICLE	NL001_STAGE 4	SOLID ROCKET MOTOR (COI MOTOR)	SOLID ROCKET MOTOR CASE STRUCTURE	0	4	2	1	0	1	0	0
1.1.1.04.03.02	NANOLAUNCHER PHASE II BASELINE	FOUR STAGE/ALL-SOLID BASELINE	NL001 VEHICLE	NL001_STAGE 4	SOLID ROCKET MOTOR (COI MOTOR)	SOLID ROCKET MOTOR CASE INSULATION	0	1	2	1	0	1	0	0
1.1.1.04.03.03	NANOLAUNCHER PHASE II BASELINE	FOUR STAGE/ALL-SOLID BASELINE	NL001 VEHICLE	NL001_STAGE 4	SOLID ROCKET MOTOR (COI MOTOR)	SOLID PROPELLANT (EXPENDED)	0	1	1	0	0	1	0	0
1.1.1.04.03.04	NANOLAUNCHER PHASE II BASELINE	FOUR STAGE/ALL-SOLID BASELINE	NL001 VEHICLE	NL001_STAGE 4	SOLID ROCKET MOTOR (COI MOTOR)	SOLID PROPELLANT (RESIDUAL)	0	1	1	0	0	1	0	0
1.1.1.04.03.05	NANOLAUNCHER PHASE II BASELINE	FOUR STAGE/ALL-SOLID BASELINE	NL001 VEHICLE	NL001_STAGE 4	SOLID ROCKET MOTOR (COI MOTOR)	EXHAUST NOZZLE	0	1	1	1	0	0	0	0
1.1.1.04.03.06	NANOLAUNCHER PHASE II BASELINE	FOUR STAGE/ALL-SOLID BASELINE	NL001 VEHICLE	NL001_STAGE 4	SOLID ROCKET MOTOR (COI MOTOR)	SOLID ROCKET MOTOR MAIN CHAMBER IGNITER SYSTEM COMPONENTS	0	2	4	2	0	2	0	0
1.1.1.04.04.01	NANOLAUNCHER PHASE II BASELINE	FOUR STAGE/ALL-SOLID BASELINE	NL001 VEHICLE	NL001_STAGE 4	ELECTRICAL POWER DISTRIBUTION	AVIONICS DC BATTERY	0	1	1	1	0	0	0	0
1.1.1.04.04.02	NANOLAUNCHER PHASE II BASELINE	FOUR STAGE/ALL-SOLID BASELINE	NL001 VEHICLE	NL001_STAGE 4	ELECTRICAL POWER DISTRIBUTION	DC POWER DISTRIBUTION UNIT	0	1	7	7	0	0	0	0
1.1.1.04.04.03	NANOLAUNCHER PHASE II BASELINE	FOUR STAGE/ALL-SOLID BASELINE	NL001 VEHICLE	NL001_STAGE 4	ELECTRICAL POWER DISTRIBUTION	POWER CABLES AND WIRING	0	1	6	6	0	0	0	0
1.1.1.04.05.01	NANOLAUNCHER PHASE II BASELINE	FOUR STAGE/ALL-SOLID BASELINE	NL001 VEHICLE	NL001_STAGE 4	COMMAND & CONTROL	FLIGHT COMPUTER	0	1	4	4	0	0	0	0
1.1.1.04.05.02	NANOLAUNCHER PHASE II BASELINE	FOUR STAGE/ALL-SOLID BASELINE	NL001 VEHICLE	NL001_STAGE 4	COMMAND & CONTROL	FLIGHT CRITICAL SOFTWARE LOAD	0	1	1	1	0	0	0	0
1.1.1.04.05.03	NANOLAUNCHER PHASE II BASELINE	FOUR STAGE/ALL-SOLID BASELINE	NL001 VEHICLE	NL001_STAGE 4	COMMAND & CONTROL	SIGNAL HARNESSES, CABLES, WIRING	0	1	4	4	0	0	0	0
1.1.1.04.05.04	NANOLAUNCHER PHASE II BASELINE	FOUR STAGE/ALL-SOLID BASELINE	NL001 VEHICLE	NL001_STAGE 4	VENT	OUTLETS & VENTS	0	1	2	2	0	0	0	0
1.1.1.04.06.01	NANOLAUNCHER PHASE II BASELINE	FOUR STAGE/ALL-SOLID BASELINE	NL001 VEHICLE	NL001_STAGE 4	NAVIGATION	INS UNIT	0	1	3	3	0	0	0	0
1.1.1.04.06.02	NANOLAUNCHER PHASE II BASELINE	FOUR STAGE/ALL-SOLID BASELINE	NL001 VEHICLE	NL001_STAGE 4	NAVIGATION	ATTITUDE CONTROL DRIVER/SIGNAL CONDITIONER	0	1	12	12	0	0	0	0
1.1.1.04.06.03	NANOLAUNCHER PHASE II BASELINE	FOUR STAGE/ALL-SOLID BASELINE	NL001 VEHICLE	NL001_STAGE 4	NAVIGATION	GPS/L-BAND ANTENNA 1	0	1	1	1	0	0	0	0
1.1.1.04.06.04	NANOLAUNCHER PHASE II BASELINE	FOUR STAGE/ALL-SOLID BASELINE	NL001 VEHICLE	NL001_STAGE 4	NAVIGATION	GPS/L-BAND ANTENNA 2	0	1	1	1	0	0	0	0
1.1.1.04.06.05	NANOLAUNCHER PHASE II BASELINE	FOUR STAGE/ALL-SOLID BASELINE	NL001 VEHICLE	NL001_STAGE 4	NAVIGATION	GPS ELECTRONICS UNIT (LNA/COMB)	0	1	4	4	0	0	0	0
1.1.1.05.01.01	NANOLAUNCHER PHASE II BASELINE	FOUR STAGE/ALL-SOLID BASELINE	NL001 VEHICLE	NL001_PAYLOAD FAIRING	STRUCTURE	FAIRING CONE SRTUCTURE	0	1	2	1	0	1	0	0
1.1.1.05.02.01	NANOLAUNCHER PHASE II BASELINE	FOUR STAGE/ALL-SOLID BASELINE	NL001 VEHICLE	NL001_PAYLOAD FAIRING	THERMAL	ABLATIVE LAYER/COATING	0	1	1	1	0	0	0	0
1.1.1.05.02.02	NANOLAUNCHER PHASE II BASELINE	FOUR STAGE/ALL-SOLID BASELINE	NL001 VEHICLE	NL001_PAYLOAD FAIRING	THERMAL	INTERNAL THERMAL/ACOUSTIC INSULATION	0	1	1	1	0	0	0	0
1.1.1.05.03.01	NANOLAUNCHER PHASE II BASELINE	FOUR STAGE/ALL-SOLID BASELINE	NL001 VEHICLE	NL001_PAYLOAD FAIRING	VENT	OUTLETS AND VENTS	0	1	1	1	0	0	0	0
1.1.1.05.04.01	NANOLAUNCHER PHASE II BASELINE	FOUR STAGE/ALL-SOLID BASELINE	NL001 VEHICLE	NL001_PAYLOAD FAIRING	SEPARATION	FAIRING SEPARATION MECHANISM (NON-PYRO)	0	1	1	1	0	0	0	0
							TOTAL	110	356	305	0	51	0	0

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APPENDIX E. SAMPLE NL001, ADVANCED AVIONICS SYSTEM DEFINITION SHEET

(created w/SBS Tool in Phase II)

SYS CODE	ARCH	TYPE	SEGMENT	ELEMENT	SUBSYSTEM	COMPONENT/ASSEMBLY	MASS	SYS_CMPLX	TOTAL_IF	NORM_IF	TOXIC_IF	ORDN_IF	CONF_SP_IF	REUSE_INDX
1.1.1.01.01.01	NANOLAUNCHER PHASE II BASELINE	FOUR STAGE/ALL-SOLID BASELINE	NL001 VEHICLE	NL001_STAGE 1	STRUCTURE	AFT SKIRT STRUCTURE (REINFORCED FOR STABILIZER FINS)	0	1	5	5	0	0	0	0
1.1.1.01.01.02	NANOLAUNCHER PHASE II BASELINE	FOUR STAGE/ALL-SOLID BASELINE	NL001 VEHICLE	NL001_STAGE 1	STRUCTURE	SYSTEMS TUNNEL COVER/FAIRING	0	1	5	5	0	0	0	0
1.1.1.01.01.03	NANOLAUNCHER PHASE II BASELINE	FOUR STAGE/ALL-SOLID BASELINE	NL001 VEHICLE	NL001_STAGE 1	STRUCTURE	FWD INTERSTAGE STRUCTURE	0	1	5	5	0	0	0	0
1.1.1.01.01.04	NANOLAUNCHER PHASE II BASELINE	FOUR STAGE/ALL-SOLID BASELINE	NL001 VEHICLE	NL001_STAGE 1	STRUCTURE	SPIN-UP SYSTEM ACCESS DOORS/PANELS (LOCATED ON FWD INTERSTAGE)	0	1	5	5	0	0	0	0
1.1.1.01.02.01	NANOLAUNCHER PHASE II BASELINE	FOUR STAGE/ALL-SOLID BASELINE	NL001 VEHICLE	NL001_STAGE 1	STABILIZATION	FIXED STABILIZER FINS (3 OR 4)	0	1	4	4	0	0	0	0
1.1.1.01.02.02	NANOLAUNCHER PHASE II BASELINE	FOUR STAGE/ALL-SOLID BASELINE	NL001 VEHICLE	NL001_STAGE 1	STABILIZATION	SPIN-UP MOTORS W/MOUNTINGS (LOCATED IN FWD INTERSTAGE)	0	1	4	0	0	4	0	0
1.1.1.01.03.01	NANOLAUNCHER PHASE II BASELINE	FOUR STAGE/ALL-SOLID BASELINE	NL001 VEHICLE	NL001_STAGE 1	SOLID ROCKET MOTOR (STAR 31)	SOLID ROCKET MOTOR CASE STRUCTURE	0	1	5	4	0	1	0	0
1.1.1.01.03.02	NANOLAUNCHER PHASE II BASELINE	FOUR STAGE/ALL-SOLID BASELINE	NL001 VEHICLE	NL001_STAGE 1	SOLID ROCKET MOTOR (STAR 31)	SOLID ROCKET MOTOR CASE INSULATION	0	1	5	4	0	1	0	0
1.1.1.01.03.03	NANOLAUNCHER PHASE II BASELINE	FOUR STAGE/ALL-SOLID BASELINE	NL001 VEHICLE	NL001_STAGE 1	SOLID ROCKET MOTOR (STAR 31)	SOLID PROPELLANT (EXPENDED)	0	1	1	0	0	1	0	0
1.1.1.01.03.04	NANOLAUNCHER PHASE II BASELINE	FOUR STAGE/ALL-SOLID BASELINE	NL001 VEHICLE	NL001_STAGE 1	SOLID ROCKET MOTOR (STAR 31)	SOLID PROPELLANT (RESIDUAL)	0	0	0	0	0	0	0	0
1.1.1.01.03.05	NANOLAUNCHER PHASE II BASELINE	FOUR STAGE/ALL-SOLID BASELINE	NL001 VEHICLE	NL001_STAGE 1	SOLID ROCKET MOTOR (STAR 31)	EXHAUST NOZZLE	0	1	1	1	0	0	0	0
1.1.1.01.03.06	NANOLAUNCHER PHASE II BASELINE	FOUR STAGE/ALL-SOLID BASELINE	NL001 VEHICLE	NL001_STAGE 1	SOLID ROCKET MOTOR (STAR 31)	SOLID ROCKET MOTOR MAIN CHAMBER IGNITER SYSTEM COMPONENTS	0	2	4	2	0	2	0	0
1.1.1.01.03.07	NANOLAUNCHER PHASE II BASELINE	FOUR STAGE/ALL-SOLID BASELINE	NL001 VEHICLE	NL001_STAGE 1	SOLID ROCKET MOTOR (STAR 31)	SENSORS (CHAMBER PRESSURE)	0	1	11	10	0	1	0	0
1.1.1.01.04.01	NANOLAUNCHER PHASE II BASELINE	FOUR STAGE/ALL-SOLID BASELINE	NL001 VEHICLE	NL001_STAGE 1	ELECTRICAL POWER DISTRIBUTION	POWER CABLING	0	1	4	2	0	2	0	0
1.1.1.01.05.01	NANOLAUNCHER PHASE II BASELINE	FOUR STAGE/ALL-SOLID BASELINE	NL001 VEHICLE	NL001_STAGE 1	THERMAL PROTECTION	THERMAL BLANKET TPS COMPONENTS (ONLY FOR LAUNCH PAD OPTION)	0	0	0	0	0	0	0	0
1.1.1.01.06.01	NANOLAUNCHER PHASE II BASELINE	FOUR STAGE/ALL-SOLID BASELINE	NL001 VEHICLE	NL001_STAGE 1	VENT	OUTLETS AND VENTS (ON FWD INTERSTAGE)	0	1	2	2	0	0	0	0
1.1.1.01.07.01	NANOLAUNCHER PHASE II BASELINE	FOUR STAGE/ALL-SOLID BASELINE	NL001 VEHICLE	NL001_STAGE 1	COMMAND & CONTROL	CABLING AND WIRING	0	1	2	2	0	0	0	0
1.1.1.01.08.01	NANOLAUNCHER PHASE II BASELINE	FOUR STAGE/ALL-SOLID BASELINE	NL001 VEHICLE	NL001_STAGE 1	SEPARATION	MECHANICAL SEPARATION COMPONENTS (E.G., SPRING SETS)	0	2	2	2	0	0	0	0
1.1.1.01.08.02	NANOLAUNCHER PHASE II BASELINE	FOUR STAGE/ALL-SOLID BASELINE	NL001 VEHICLE	NL001_STAGE 1	SEPARATION	ORDNANCE (IF REQUIRED)	0	0	0	0	0	0	0	0
1.1.1.01.09.01	NANOLAUNCHER PHASE II BASELINE	FOUR STAGE/ALL-SOLID BASELINE	NL001 VEHICLE	NL001_STAGE 1	RAIL (FLT HALF)	LAUNCH RAIL INTERFACE SRUCTURAL/MECHANICAL EQUIPMENT (FLT HALF)	0	1	1	1	0	0	0	0
1.1.1.02.01.01	NANOLAUNCHER PHASE II BASELINE	FOUR STAGE/ALL-SOLID BASELINE	NL001 VEHICLE	NL001_STAGE 2	STRUCTURE	AFT INTERSTAGE STRUCTURE (REINFORCED FOR STABILIZER FINS)	0	1	5	5	0	0	0	0
1.1.1.02.01.02	NANOLAUNCHER PHASE II BASELINE	FOUR STAGE/ALL-SOLID BASELINE	NL001 VEHICLE	NL001_STAGE 2	STRUCTURE	SYSTEMS TUNNEL COVER/FAIRING	0	1	2	2	0	0	0	0
1.1.1.02.01.03	NANOLAUNCHER PHASE II BASELINE	FOUR STAGE/ALL-SOLID BASELINE	NL001 VEHICLE	NL001_STAGE 2	STRUCTURE	FWD INTERSTAGE STRUCTURE	0	1	2	2	0	0	0	0
1.1.1.02.01.04	NANOLAUNCHER PHASE II BASELINE	FOUR STAGE/ALL-SOLID BASELINE	NL001 VEHICLE	NL001_STAGE 2	STRUCTURE	FWD INTERSTAGE ACCESS PANELS	0	1	1	1	0	0	0	0
1.1.1.02.02.01	NANOLAUNCHER PHASE II BASELINE	FOUR STAGE/ALL-SOLID BASELINE	NL001 VEHICLE	NL001_STAGE 2	STABILIZATION	FIXED STABILIZER FINS	0	1	1	1	0	0	0	0
1.1.1.02.03.01	NANOLAUNCHER PHASE II BASELINE	FOUR STAGE/ALL-SOLID BASELINE	NL001 VEHICLE	NL001_STAGE 2	SOLID ROCKET MOTOR (STAR 20B-LIKE)	SOLID ROCKET MOTOR CASE STRUCTURE	0	1	5	4	0	1	0	0
1.1.1.02.03.02	NANOLAUNCHER PHASE II BASELINE	FOUR STAGE/ALL-SOLID BASELINE	NL001 VEHICLE	NL001_STAGE 2	SOLID ROCKET MOTOR (STAR 20B-LIKE)	SOLID ROCKET MOTOR CASE INSULATION	0	1	2	1	0	1	0	0
1.1.1.02.03.03	NANOLAUNCHER PHASE II BASELINE	FOUR STAGE/ALL-SOLID BASELINE	NL001 VEHICLE	NL001_STAGE 2	SOLID ROCKET MOTOR (STAR 20B-LIKE)	SOLID PROPELLANT (EXPENDED)	0	1	1	0	0	1	0	0
1.1.1.02.03.04	NANOLAUNCHER PHASE II BASELINE	FOUR STAGE/ALL-SOLID BASELINE	NL001 VEHICLE	NL001_STAGE 2	SOLID ROCKET MOTOR (STAR 20B-LIKE)	SOLID PROPELLANT (RESIDUAL)	0	0	0	0	0	0	0	0
1.1.1.02.03.05	NANOLAUNCHER PHASE II BASELINE	FOUR STAGE/ALL-SOLID BASELINE	NL001 VEHICLE	NL001_STAGE 2	SOLID ROCKET MOTOR (STAR 20B-LIKE)	EXHAUST NOZZLE	0	1	1	1	0	0	0	0
1.1.1.02.03.06	NANOLAUNCHER PHASE II BASELINE	FOUR STAGE/ALL-SOLID BASELINE	NL001 VEHICLE	NL001_STAGE 2	SOLID ROCKET MOTOR (STAR 20B-LIKE)	SOLID ROCKET MOTOR MAIN CHAMBER IGNITER SYSTEM COMPONENTS	0	2	4	2	0	2	0	0
1.1.1.02.03.07	NANOLAUNCHER PHASE II BASELINE	FOUR STAGE/ALL-SOLID BASELINE	NL001 VEHICLE	NL001_STAGE 2	SOLID ROCKET MOTOR (STAR 20B-LIKE)	SENSORS (CHAMBER PRESSURE)	0	1	11	10	0	1	0	0
1.1.1.02.04.01	NANOLAUNCHER PHASE II BASELINE	FOUR STAGE/ALL-SOLID BASELINE	NL001 VEHICLE	NL001_STAGE 2	ELECTRICAL POWER DISTRIBUTION	POWER CABLING	0	1	4	2	0	2	0	0
1.1.1.02.05.01	NANOLAUNCHER PHASE II BASELINE	FOUR STAGE/ALL-SOLID BASELINE	NL001 VEHICLE	NL001_STAGE 2	VENT	OUTLETS AND VENTS (ON FWD INTERSTAGE)	0	1	2	2	0	0	0	0
1.1.1.02.06.01	NANOLAUNCHER PHASE II BASELINE	FOUR STAGE/ALL-SOLID BASELINE	NL001 VEHICLE	NL001_STAGE 2	COMMAND & CONTROL	CABLING AND WIRING	0	1	2	2	0	0	0	0
1.1.1.02.07.01	NANOLAUNCHER PHASE II BASELINE	FOUR STAGE/ALL-SOLID BASELINE	NL001 VEHICLE	NL001_STAGE 2	SEPARATION	MECHANICAL SEPARATION COMPONENTS (E.G., SPRING SETS)	0	1	2	2	0	0	0	0
1.1.1.02.08.01	NANOLAUNCHER PHASE II BASELINE	FOUR STAGE/ALL-SOLID BASELINE	NL001 VEHICLE	NL001_STAGE 2	RAIL (FLT HALF)	LAUNCH RAIL INTERFACE STRUCTURAL/MECHANICAL EQUIPMENT (FLIGHT HALF)	0	1	1	1	0	0	0	0
1.1.1.03.01.01	NANOLAUNCHER PHASE II BASELINE	FOUR STAGE/ALL-SOLID BASELINE	NL001 VEHICLE	NL001_STAGE 3	STRUCTURE	AFT INTERSTAGE STRUCTURE (REINFORCED FOR STABILIZER FINS)	0	1	5	5	0	0	0	0
1.1.1.03.01.02	NANOLAUNCHER PHASE II BASELINE	FOUR STAGE/ALL-SOLID BASELINE	NL001 VEHICLE	NL001_STAGE 3	STRUCTURE	SYSTEMS TUNNEL COVER/FAIRING	0	1	2	2	0	0	0	0
1.1.1.03.01.03	NANOLAUNCHER PHASE II BASELINE	FOUR STAGE/ALL-SOLID BASELINE	NL001 VEHICLE	NL001_STAGE 3	STRUCTURE	FWD INTERSTAGE STRUCTURE	0	1	3	2	0	1	0	0
1.1.1.03.01.04	NANOLAUNCHER PHASE II BASELINE	FOUR STAGE/ALL-SOLID BASELINE	NL001 VEHICLE	NL001_STAGE 3	STRUCTURE	FWD INTERSTAGE ACCESS PANELS	0	1	1	1	0	0	0	0
1.1.1.03.01.05	NANOLAUNCHER PHASE II BASELINE	FOUR STAGE/ALL-SOLID BASELINE	NL001 VEHICLE	NL001_STAGE 3	STRUCTURE	AFT INTERSTAGE ACCESS PANELS	0	1	1	1	0	0	0	0
1.1.1.03.01.06	NANOLAUNCHER PHASE II BASELINE	FOUR STAGE/ALL-SOLID BASELINE	NL001 VEHICLE	NL001_STAGE 3	STRUCTURE	THIRD/FOURTH STAGE ADAPTER STRUCTURE	0	1	4	4	0	0	0	0
1.1.1.03.02.01	NANOLAUNCHER PHASE II BASELINE	FOUR STAGE/ALL-SOLID BASELINE	NL001 VEHICLE	NL001_STAGE 3	STABILIZATION	DE-SPIN/YO-YO COMPONENTS/ASSEMBLY	0	2	6	5	0	1	0	0
1.1.1.03.03.01	NANOLAUNCHER PHASE II BASELINE	FOUR STAGE/ALL-SOLID BASELINE	NL001 VEHICLE	NL001_STAGE 3	SOLID ROCKET MOTOR (STAR 15G-LIKE)	SOLID ROCKET MOTOR CASE STRUCTURE	0	1	5	4	0	1	0	0
1.1.1.03.03.02	NANOLAUNCHER PHASE II BASELINE	FOUR STAGE/ALL-SOLID BASELINE	NL001 VEHICLE	NL001_STAGE 3	SOLID ROCKET MOTOR (STAR 15G-LIKE)	SOLID ROCKET MOTOR CASE INSULATION	0	1	2	1	0	1	0	0
1.1.1.03.03.03	NANOLAUNCHER PHASE II BASELINE	FOUR STAGE/ALL-SOLID BASELINE	NL001 VEHICLE	NL001_STAGE 3	SOLID ROCKET MOTOR (STAR 15G-LIKE)	SOLID PROPELLANT (EXPENDED)	0	1	1	0	0	1	0	0
1.1.1.03.03.04	NANOLAUNCHER PHASE II BASELINE	FOUR STAGE/ALL-SOLID BASELINE	NL001 VEHICLE	NL001_STAGE 3	SOLID ROCKET MOTOR (STAR 15G-LIKE)	SOLID PROPELLANT (RESIDUAL)	0	0	0	0	0	0	0	0
1.1.1.03.03.05	NANOLAUNCHER PHASE II BASELINE	FOUR STAGE/ALL-SOLID BASELINE	NL001 VEHICLE	NL001_STAGE 3	SOLID ROCKET MOTOR (STAR 15G-LIKE)	EXHAUST NOZZLE	0	1	1	1	0	0	0	0
1.1.1.03.03.06	NANOLAUNCHER PHASE II BASELINE	FOUR STAGE/ALL-SOLID BASELINE	NL001 VEHICLE	NL001_STAGE 3	SOLID ROCKET MOTOR (STAR 15G-LIKE)	SOLID ROCKET MOTOR MAIN CHAMBER IGNITER SYSTEM COMPONENTS	0	2	4	2	0	2	0	0
1.1.1.03.03.07	NANOLAUNCHER PHASE II BASELINE	FOUR STAGE/ALL-SOLID BASELINE	NL001 VEHICLE	NL001_STAGE 3	SOLID ROCKET MOTOR (STAR 15G-LIKE)	SENSORS (CHAMBER PRESSURE)	0	1	11	10	0	1	0	0
1.1.1.03.04.01	NANOLAUNCHER PHASE II BASELINE	FOUR STAGE/ALL-SOLID BASELINE	NL001 VEHICLE	NL001_STAGE 3	ELECTRICAL POWER	-----------------ELIMINATED-----AVIONICS DC BATTERY	0	0	0	0	0	0	0	0
1.1.1.03.04.02	NANOLAUNCHER PHASE II BASELINE	FOUR STAGE/ALL-SOLID BASELINE	NL001 VEHICLE	NL001_STAGE 3	ELECTRICAL POWER	-----------------REDUCED-----DC POWER DISTRIBUTION UNIT	0	1	2	2	0	0	0	0
1.1.1.03.04.03	NANOLAUNCHER PHASE II BASELINE	FOUR STAGE/ALL-SOLID BASELINE	NL001 VEHICLE	NL001_STAGE 3	ELECTRICAL POWER	-----------------REDUCED-----ELECTRIC POWER HARNESSES, CABLES, WIRING	0	1	2	2	0	1	0	0
1.1.1.03.05.01	NANOLAUNCHER PHASE II BASELINE	FOUR STAGE/ALL-SOLID BASELINE	NL001 VEHICLE	NL001_STAGE 3	VENT	OUTLETS & VENTS	0	1	2	2	0	0	0	0
1.1.1.03.06.01	NANOLAUNCHER PHASE II BASELINE	FOUR STAGE/ALL-SOLID BASELINE	NL001 VEHICLE	NL001_STAGE 3	COMMAND & CONTROL	-----------------REDUCED-----SIGNAL HARNESSES, CABLES, WIRING	0	1	5	6	0	1	0	0
1.1.1.03.07.01	NANOLAUNCHER PHASE II BASELINE	FOUR STAGE/ALL-SOLID BASELINE	NL001 VEHICLE	NL001_STAGE 3	COMMUNICATIONS	-----------------ELIMINATED-----TM ENCODER UNIT	0	0	0	0	0	0	0	0
1.1.1.03.07.05	NANOLAUNCHER PHASE II BASELINE	FOUR STAGE/ALL-SOLID BASELINE	NL001 VEHICLE	NL001_STAGE 3	COMMUNICATIONS	S-BAND ANTENNA 1	0	1	1	1	0	0	0	0
1.1.1.03.07.05	NANOLAUNCHER PHASE II BASELINE	FOUR STAGE/ALL-SOLID BASELINE	NL001 VEHICLE	NL001_STAGE 3	COMMUNICATIONS	C-BAND RADAR BEACON ANTENNA 1	0	1	1	1	0	0	0	0
1.1.1.03.07.06	NANOLAUNCHER PHASE II BASELINE	FOUR STAGE/ALL-SOLID BASELINE	NL001 VEHICLE	NL001_STAGE 3	COMMUNICATIONS	S-BAND ANTENNA 2	0	1	1	1	0	0	0	0
1.1.1.03.07.06	NANOLAUNCHER PHASE II BASELINE	FOUR STAGE/ALL-SOLID BASELINE	NL001 VEHICLE	NL001_STAGE 3	COMMUNICATIONS	C-BAND RADAR BEACON ANTENNA 2	0	1	1	1	0	0	0	0
1.1.1.03.07.07	NANOLAUNCHER PHASE II BASELINE	FOUR STAGE/ALL-SOLID BASELINE	NL001 VEHICLE	NL001_STAGE 3	COMMUNICATIONS	-----------------ELIMINATED-----S-BAND TRANSPONDER	0	0	0	0	0	0	0	0
1.1.1.03.07.07	NANOLAUNCHER PHASE II BASELINE	FOUR STAGE/ALL-SOLID BASELINE	NL001 VEHICLE	NL001_STAGE 3	COMMUNICATIONS	-----------------ELIMINATED-----C-BAND RADAR BEACON UNIT	0	0	0	0	0	0	0	0
1.1.1.03.08.02	NANOLAUNCHER PHASE II BASELINE	FOUR STAGE/ALL-SOLID BASELINE	NL001 VEHICLE	NL001_STAGE 3	NAVIGATION	GPS/L-BAND ANTENNA 1	0	1	1	1	0	0	0	0
1.1.1.03.08.02	NANOLAUNCHER PHASE II BASELINE	FOUR STAGE/ALL-SOLID BASELINE	NL001 VEHICLE	NL001_STAGE 3	NAVIGATION	ATTITUDE CONTROL DRIVER/SIGNAL CONDITIONER	0	1	12	12	0	0	0	0
1.1.1.03.08.03	NANOLAUNCHER PHASE II BASELINE	FOUR STAGE/ALL-SOLID BASELINE	NL001 VEHICLE	NL001_STAGE 3	NAVIGATION	GPS/L-BAND ANTENNA 2	0	1	1	1	0	0	0	0
1.1.1.03.08.04	NANOLAUNCHER PHASE II BASELINE	FOUR STAGE/ALL-SOLID BASELINE	NL001 VEHICLE	NL001_STAGE 3	NAVIGATION	-----------------ELIMINATED-----GPS ELECTRONICS (LNA/COMB FILTER/RECEIVER)	0	0	0	0	0	0	0	0
1.1.1.03.08.05	NANOLAUNCHER PHASE II BASELINE	FOUR STAGE/ALL-SOLID BASELINE	NL001 VEHICLE	NL001_STAGE 3	NAVIGATION	-----------------ELIMINATED-----INS UNIT	0	0	0	0	0	0	0	0
1.1.1.03.09.01	NANOLAUNCHER PHASE II BASELINE	FOUR STAGE/ALL-SOLID BASELINE	NL001 VEHICLE	NL001_STAGE 3	FLIGHT TERMINATION	UHF FLT TERMINATION ANTENNA 1	0	1	1	1	0	0	0	0
1.1.1.03.09.02	NANOLAUNCHER PHASE II BASELINE	FOUR STAGE/ALL-SOLID BASELINE	NL001 VEHICLE	NL001_STAGE 3	FLIGHT TERMINATION	UHF FLT TERMINATION ANTENNA 2	0	1	1	1	0	0	0	0
1.1.1.03.09.03	NANOLAUNCHER PHASE II BASELINE	FOUR STAGE/ALL-SOLID BASELINE	NL001 VEHICLE	NL001_STAGE 3	FLIGHT TERMINATION	-----------------ELIMINATED-----FLT TERMINATION RECEIVER 1	0	0	0	0	0	0	0	0
1.1.1.03.09.04	NANOLAUNCHER PHASE II BASELINE	FOUR STAGE/ALL-SOLID BASELINE	NL001 VEHICLE	NL001_STAGE 3	FLIGHT TERMINATION	-----------------ELIMINATED-----FLT TERMINATION RECEIVER 2	0	0	0	0	0	0	0	0
1.1.1.03.09.05	NANOLAUNCHER PHASE II BASELINE	FOUR STAGE/ALL-SOLID BASELINE	NL001 VEHICLE	NL001_STAGE 3	FLIGHT TERMINATION	-----------------ELIMINATED-----FLT TERMINATION BATTERY 1	0	0	0	0	0	0	0	0
1.1.1.03.09.06	NANOLAUNCHER PHASE II BASELINE	FOUR STAGE/ALL-SOLID BASELINE	NL001 VEHICLE	NL001_STAGE 3	FLIGHT TERMINATION	-----------------ELIMINATED-----FLT TERMINATION BATTERY 2	0	0	0	0	0	0	0	0
1.1.1.03.09.07	NANOLAUNCHER PHASE II BASELINE	FOUR STAGE/ALL-SOLID BASELINE	NL001 VEHICLE	NL001_STAGE 3	FLIGHT TERMINATION	FLT TERMINATION SYSTEM ORDNANCE DRIVER UNIT	0	1	6	0	0	6	0	0
1.1.1.03.09.08	NANOLAUNCHER PHASE II BASELINE	FOUR STAGE/ALL-SOLID BASELINE	NL001 VEHICLE	NL001_STAGE 3	FLIGHT TERMINATION	DESTRUCT ORDNANCE (THRID AND FOURTH STG)	0	2	2	0	0	2	0	0
1.1.1.03.10.01	NANOLAUNCHER PHASE II BASELINE	FOUR STAGE/ALL-SOLID BASELINE	NL001 VEHICLE	NL001_STAGE 3	SEPARATION	MECHANICAL SEPARATION COMPONENTS/ASSEMBLY	0	2	2	2	0	0	0	0
1.1.1.04.01.01	NANOLAUNCHER PHASE II BASELINE	FOUR STAGE/ALL-SOLID BASELINE	NL001 VEHICLE	NL001_STAGE 4	STRUCTURE	ADAPTER RING STRUCTURE	0	2	3	3	0	0	0	0
1.1.1.04.02.01	NANOLAUNCHER PHASE II BASELINE	FOUR STAGE/ALL-SOLID BASELINE	NL001 VEHICLE	NL001_STAGE 4	ATTITUDE CONTROL	REACTION CONTROL JETS/MODULES	0	1	24	24	0	0	0	0
1.1.1.04.02.02	NANOLAUNCHER PHASE II BASELINE	FOUR STAGE/ALL-SOLID BASELINE	NL001 VEHICLE	NL001_STAGE 4	ATTITUDE CONTROL	REACTION CONTROL PROPELLANT STORAGE AND DISTRIBUTION	0	1	14	14	0	0	0	0
1.1.1.04.03.01	NANOLAUNCHER PHASE II BASELINE	FOUR STAGE/ALL-SOLID BASELINE	NL001 VEHICLE	NL001_STAGE 4	SOLID ROCKET MOTOR (COI MOTOR)	SOLID ROCKET MOTOR CASE STRUCTURE	0	4	2	1	0	1	0	0
1.1.1.04.03.02	NANOLAUNCHER PHASE II BASELINE	FOUR STAGE/ALL-SOLID BASELINE	NL001 VEHICLE	NL001_STAGE 4	SOLID ROCKET MOTOR (COI MOTOR)	SOLID ROCKET MOTOR CASE INSULATION	0	1	2	1	0	1	0	0
1.1.1.04.03.03	NANOLAUNCHER PHASE II BASELINE	FOUR STAGE/ALL-SOLID BASELINE	NL001 VEHICLE	NL001_STAGE 4	SOLID ROCKET MOTOR (COI MOTOR)	SOLID PROPELLANT (EXPENDED)	0	1	1	0	0	1	0	0
1.1.1.04.03.04	NANOLAUNCHER PHASE II BASELINE	FOUR STAGE/ALL-SOLID BASELINE	NL001 VEHICLE	NL001_STAGE 4	SOLID ROCKET MOTOR (COI MOTOR)	SOLID PROPELLANT (RESIDUAL)	0	1	1	0	0	1	0	0
1.1.1.04.03.05	NANOLAUNCHER PHASE II BASELINE	FOUR STAGE/ALL-SOLID BASELINE	NL001 VEHICLE	NL001_STAGE 4	SOLID ROCKET MOTOR (COI MOTOR)	EXHAUST NOZZLE	0	1	1	1	0	0	0	0
1.1.1.04.03.06	NANOLAUNCHER PHASE II BASELINE	FOUR STAGE/ALL-SOLID BASELINE	NL001 VEHICLE	NL001_STAGE 4	SOLID ROCKET MOTOR (COI MOTOR)	SOLID ROCKET MOTOR MAIN CHAMBER IGNITER SYSTEM COMPONENTS	0	2	4	2	0	2	0	0
1.1.1.04.04.01	NANOLAUNCHER PHASE II BASELINE	FOUR STAGE/ALL-SOLID BASELINE	NL001 VEHICLE	NL001_STAGE 4	ELECTRICAL POWER DISTRIBUTION	-----------------ELIMINATED-----AVIONICS DC BATTERY	0	0	0	0	0	0	0	0
1.1.1.04.04.02	NANOLAUNCHER PHASE II BASELINE	FOUR STAGE/ALL-SOLID BASELINE	NL001 VEHICLE	NL001_STAGE 4	ELECTRICAL POWER DISTRIBUTION	-----------------REDUCED-----DC POWER DISTRIBUTION UNIT	0	1	2	2	0	0	0	0
1.1.1.04.04.03	NANOLAUNCHER PHASE II BASELINE	FOUR STAGE/ALL-SOLID BASELINE	NL001 VEHICLE	NL001_STAGE 4	ELECTRICAL POWER DISTRIBUTION	-----------------REDUCED-----ELECTRIC POWER HARNESSES, CABLES, WIRING	0	1	3	3	0	0	0	0
1.1.1.04.05.01	NANOLAUNCHER PHASE II BASELINE	FOUR STAGE/ALL-SOLID BASELINE	NL001 VEHICLE	NL001_STAGE 4	COMMAND & CONTROL	ADVANCED AVIONICS UNIT (INTERNALLY DUAL REDUNDANT)	0	1	4	4	0	0	0	0
1.1.1.04.05.02	NANOLAUNCHER PHASE II BASELINE	FOUR STAGE/ALL-SOLID BASELINE	NL001 VEHICLE	NL001_STAGE 4	COMMAND & CONTROL	FLIGHT CRITICAL SOFTWARE LOAD	0	1	1	1	0	0	0	0
1.1.1.04.05.03	NANOLAUNCHER PHASE II BASELINE	FOUR STAGE/ALL-SOLID BASELINE	NL001 VEHICLE	NL001_STAGE 4	COMMAND & CONTROL	-----------------REDUCED-----SIGNAL HARNESSES, CABLES, WIRING	0	1	2	2	0	0	0	0
1.1.1.04.05.04	NANOLAUNCHER PHASE II BASELINE	FOUR STAGE/ALL-SOLID BASELINE	NL001 VEHICLE	NL001_STAGE 4	VENT	OUTLETS & VENTS	0	1	2	2	0	0	0	0
1.1.1.04.06.01	NANOLAUNCHER PHASE II BASELINE	FOUR STAGE/ALL-SOLID BASELINE	NL001 VEHICLE	NL001_STAGE 4	NAVIGATION	-----------------ELIMINATED-----INS UNIT	0	0	0	0	0	0	0	0
1.1.1.04.06.02	NANOLAUNCHER PHASE II BASELINE	FOUR STAGE/ALL-SOLID BASELINE	NL001 VEHICLE	NL001_STAGE 4	NAVIGATION	ATTITUDE CONTROL DRIVER/SIGNAL CONDITIONER	0	1	12	12	0	0	0	0
1.1.1.04.06.03	NANOLAUNCHER PHASE II BASELINE	FOUR STAGE/ALL-SOLID BASELINE	NL001 VEHICLE	NL001_STAGE 4	NAVIGATION	GPS/L-BAND ANTENNA 1	0	1	1	1	0	0	0	0
1.1.1.04.06.04	NANOLAUNCHER PHASE II BASELINE	FOUR STAGE/ALL-SOLID BASELINE	NL001 VEHICLE	NL001_STAGE 4	NAVIGATION	GPS/L-BAND ANTENNA 2	0	1	1	1	0	0	0	0
1.1.1.04.06.05	NANOLAUNCHER PHASE II BASELINE	FOUR STAGE/ALL-SOLID BASELINE	NL001 VEHICLE	NL001_STAGE 4	NAVIGATION	-----------------ELIMINATED-----GPS ELECTRONICS UNIT (LNA/COMB)	0	0	0	0	0	0	0	0
1.1.1.05.01.01	NANOLAUNCHER PHASE II BASELINE	FOUR STAGE/ALL-SOLID BASELINE	NL001 VEHICLE	NL001_PAYLOAD FAIRING	STRUCTURE	FAIRING CONE SRTUCTURE	0	1	2	1	0	1	0	0
1.1.1.05.02.01	NANOLAUNCHER PHASE II BASELINE	FOUR STAGE/ALL-SOLID BASELINE	NL001 VEHICLE	NL001_PAYLOAD FAIRING	THERMAL	ABLATIVE LAYER/COATING	0	1	1	1	0	0	0	0
1.1.1.05.02.02	NANOLAUNCHER PHASE II BASELINE	FOUR STAGE/ALL-SOLID BASELINE	NL001 VEHICLE	NL001_PAYLOAD FAIRING	THERMAL	INTERNAL THERMAL/ACOUSTIC INSULATION	0	1	1	1	0	0	0	0
1.1.1.05.03.01	NANOLAUNCHER PHASE II BASELINE	FOUR STAGE/ALL-SOLID BASELINE	NL001 VEHICLE	NL001_PAYLOAD FAIRING	VENT	OUTLETS AND VENTS	0	1	1	1	0	0	0	0
1.1.1.05.04.01	NANOLAUNCHER PHASE II BASELINE	FOUR STAGE/ALL-SOLID BASELINE	NL001 VEHICLE	NL001_PAYLOAD FAIRING	SEPARATION	FAIRING SEPARATION MECHANISM (NON-PYRO)	0	1	1	1	0	0	0	0
						NL001 VEH ROLL-UP W/ ADVANCED AVIONICS-->	TOTAL	97	285	243	0	45	0	0
						NL001 VEH ROLL-UP W/ BASELINE AVIONICS-->	TOTAL	110	356	305	0	51	0	0

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APPENDIX F. SAMPLE NL001, BASELINE WITH FUNCTIONAL SYSTEM DEFINITION

(created w/SBS Tool in Phase II)

SYS CODE	**SUBSYSTEM**	**COMPONENT/ASSEMBLY**	FUNCTION CODE	DISCIPLINE FUNCTION DESCRIPTION	FUNCTION DESCRIPTION	SUBFUNCTION DESCRIPTION
1.1.1.01.01.01	STRUCTURE	AFT SKIRT STRUCTURE (REINFORCED FOR STABILIZER FINS)	A3.B3.C1.D1.E1.F1.G1	STRUCTURAL CONTAINMENT AND SUPPORT	BODY/FRAMEWORK FUNCTION - CONTAIN VEHICLE FUNCTIONS AND SUPPOR	BODY/FRAMEWORK COMPARTMENTALIZATION
1.1.1.01.01.02	STRUCTURE	SYSTEMS TUNNEL COVER/FAIRING	A3.B3.C1.D1.E1.F2.G1	STRUCTURAL CONTAINMENT AND SUPPORT	NON-BODY/FRAMEWORK FUNCTIONS - ATTACHMENT TO BODY/FRAMEWORK	NON-BODY/FRAMEWORK COMPARTMENTALIZATION
1.1.1.01.01.03	STRUCTURE	FWD INTERSTAGE STRUCTURE	A3.B3.C1.D1.E1.F5.G1	STRUCTURAL CONTAINMENT AND SUPPORT	CONNECT AND ATTACH ELEMENTS	FLIGHT-TO-FLIGHT STRUCTURAL CONNECTION AND ATTACHMENT
1.1.1.01.01.04	STRUCTURE	SPIN-UP SYSTEM ACCESS DOORS/PANELS (LOCATED ON FWD INTERSTAGE)	A3.B3.C1.D1.E1.F2.G1	STRUCTURAL CONTAINMENT AND SUPPORT	NON-BODY/FRAMEWORK FUNCTIONS - ATTACHMENT TO BODY/FRAMEWORK	NON-BODY/FRAMEWORK COMPARTMENTALIZATION
1.1.1.01.02.01	STABILIZATION	FIXED STABILIZER FINS (3 OR 4)	A3.B3.C1.D1.E2.F1.G2	VEHICLE STABILITY AND CONTROL	AERODYNAMIC STABILITY AND CONTROL (INCLUDING STRUCTURAL SURFACE, I	AERODYNAMIC VEHICLE STABILIZATION AND/OR CONTROL
1.1.1.01.02.02	STABILIZATION	SPIN-UP MOTORS W/MOUNTINGS (LOCATED IN FWD INTERSTAGE)	A3.B3.C1.D1.E2.F4.G1	VEHICLE STABILITY AND CONTROL	VEHICLE SPIN STABILIZATION (AND/OR DE-SPIN)	PROPULSIVE VEHICLE SPIN-UP (AND/OR DE-SPIN)
1.1.1.01.03.01	SOLID ROCKET MOTOR (STAR 31)	SOLID ROCKET MOTOR CASE STRUCTURE	A3.B3.C1.D1.E3.F1.G2	MAIN PROPULSION	MAIN PROPELLANT STORAGE & DISTRIBUTION	MAIN PROPELLANT STORAGE AND CONTAINMENT
1.1.1.01.03.02	SOLID ROCKET MOTOR (STAR 31)	SOLID ROCKET MOTOR CASE INSULATION	A3.B3.C1.D1.E3.F1.G2	MAIN PROPULSION	MAIN PROPELLANT STORAGE & DISTRIBUTION	MAIN PROPELLANT STORAGE AND CONTAINMENT
1.1.1.01.03.03	SOLID ROCKET MOTOR (STAR 31)	SOLID PROPELLANT (EXPENDED)	A3.B3.C1.D1.E3.F7.G1	MAIN PROPULSION	SUPPLY MAIN ON-BOARD REACTION MASS	SUPPLY MAIN REACTION MASS
1.1.1.01.03.04	SOLID ROCKET MOTOR (STAR 31)	SOLID PROPELLANT (RESIDUAL)	A3.B3.C1.D1.E3.F7.G2	MAIN PROPULSION	SUPPLY MAIN ON-BOARD REACTION MASS	SUPPLY MAIN REACTION MASS BIAS/MARGIN
1.1.1.01.03.05	SOLID ROCKET MOTOR (STAR 31)	EXHAUST NOZZLE	A3.B3.C1.D1.E3.F5.G5	MAIN PROPULSION	MAIN THRUST GENERATION/POWER PLANT FUNCTION	MAIN PROPULSION NOZZLE/EXHAUST GAS MANAGEMENT (EXPULSION/EXPANSION OF COMBUSTI
1.1.1.01.03.06	SOLID ROCKET MOTOR (STAR 31)	SOLID ROCKET MOTOR MAIN CHAMBER IGNITER SYSTEM COMPONENTS	A3.B3.C1.D1.E3.F5.G3	MAIN PROPULSION	MAIN THRUST GENERATION/POWER PLANT FUNCTION	STARTING/IGNITION FOR MAIN PROPULSION
1.1.1.01.03.07	SOLID ROCKET MOTOR (STAR 31)	SENSORS (CHAMBER PRESSURE)	A3.B3.C1.D1.E3.F6.G5	MAIN PROPULSION	MAIN PROPELLANT FLOW PATH MANAGEMENT	MAIN PROPULSION SYSTEM SENSOR DATA COLLECTION AND SIGNAL CONDITIONING
1.1.1.01.04.01	ELECTRICAL POWER DISTRIBUTION	POWER CABLING	A3.B3.C1.D1.E5.F3.G2	ELECTRICAL POWER GENERATION, CONTROL, AND DISTR	ELECTRICAL POWER DISTRIBUTION	DISTRIBUTE ELECTRICAL POWER
1.1.1.01.05.01	THERMAL PROTECTION	THERMAL BLANKET TPS COMPONENTS (ONLY FOR LAUNCH PAD OPTION)	A3.B3.C1.D1.E7.F2.G2	THERMAL PROTECTION	PERMANENT THERMAL PROTECTION	EXTERNALLY PROTECT "COLD STRUCTURE" (I.E., INSULATE THROUGH ATTACHED MATERIALS)
1.1.1.01.06.01	VENT	OUTLETS AND VENTS (ON FWD INTERSTAGE)	A3.B3.C1.D1.E8.F3.G3	ENVIRONMENTAL AND ACTIVE THERMAL CONTROL	VEHICLE ENVIRONMENTAL PRESSURIZATION/MOISTURE CONTROL	VEHICLE STRUCTURE VENTING
1.1.1.01.07.01	COMMAND & CONTROL	CABLING AND WIRING	A3.B3.C1.D1.E9.F1.G2	COMMAND AND DATA MANAGEMENT	VEH SYSTEMS COMMAND & DATA DISTRIBUTION/SIGNAL CONDITIONING	VEH SYSTEMS SIGNAL CONVERSION, AMPLIFICATION & DISTRIBUTION
1.1.1.01.08.01	SEPARATION	MECHANICAL SEPARATION COMPONENTS (E.G., SPRING SETS)	A3.B3.C1.D1.E15.F1.G1	STAGE/ELEMENT SEPARATION	SEPARATING WITHOUT EXPLOSIVES	ROUTINE MECHANICAL STAGE/ELEMENT SEPARATION/JETTISON (E.G., SPRING SETS)
1.1.1.01.08.02	SEPARATION	ORDNANCE (IF REQUIRED)	A3.B3.C1.D1.E15.F2.G1	STAGE/ELEMENT SEPARATION	EXPLOSIVELY SEPARATING	ROUTINE STAGE/ELEMENT SEPARATION/JETTISON MOTORS
1.1.1.01.09.01	RAIL (FLT HALF)	LAUNCH RAIL INTERFACE SRUCTURAL/MECHANICAL EQUIPMENT (FLT HALF)	A3.B3.C1.D1.E16.F2.G1	LAUNCH/TAKEOFF AND LANDING SUPPORT	GROUND LAUNCH ASSIST	PASSIVE GROUND LAUNCH RAIL INTERFACING (FLIGHT HALF FUNCTION)
1.1.1.02.01.01	STRUCTURE	AFT INTERSTAGE STRUCTURE (REINFORCED FOR STABILIZER FINS)	A3.B3.C1.D3.E1.F5.G1	STRUCTURAL CONTAINMENT AND SUPPORT	CONNECT AND ATTACH ELEMENTS	FLIGHT-TO-FLIGHT STRUCTURAL CONNECTION AND ATTACHMENT
1.1.1.02.01.02	STRUCTURE	SYSTEMS TUNNEL COVER/FAIRING	A3.B3.C1.D3.E1.F2.G1	STRUCTURAL CONTAINMENT AND SUPPORT	NON-BODY/FRAMEWORK FUNCTIONS - ATTACHMENT TO BODY/FRAMEWORK	NON-BODY/FRAMEWORK COMPARTMENTALIZATION
1.1.1.02.01.03	STRUCTURE	FWD INTERSTAGE STRUCTURE	A3.B3.C1.D3.E1.F5.G1	STRUCTURAL CONTAINMENT AND SUPPORT	CONNECT AND ATTACH ELEMENTS	FLIGHT-TO-FLIGHT STRUCTURAL CONNECTION AND ATTACHMENT
1.1.1.02.01.04	STRUCTURE	FWD INTERSTAGE ACCESS PANELS	A3.B3.C1.D3.E1.F2.G1	STRUCTURAL CONTAINMENT AND SUPPORT	NON-BODY/FRAMEWORK FUNCTIONS - ATTACHMENT TO BODY/FRAMEWORK	NON-BODY/FRAMEWORK COMPARTMENTALIZATION
1.1.1.02.02.01	STABILIZATION	FIXED STABILIZER FINS	A3.B3.C1.D3.E2.F1.G2	VEHICLE STABILITY AND CONTROL	AERODYNAMIC STABILITY AND CONTROL (INCLUDING STRUCTURAL SURFACE, I	AERODYNAMIC VEHICLE STABILIZATION AND/OR CONTROL
1.1.1.02.03.01	SOLID ROCKET MOTOR (STAR 20B-LIKE)	SOLID ROCKET MOTOR CASE STRUCTURE	A3.B3.C1.D3.E3.F1.G2	MAIN PROPULSION	MAIN PROPELLANT STORAGE & DISTRIBUTION	MAIN PROPELLANT STORAGE AND CONTAINMENT
1.1.1.02.03.02	SOLID ROCKET MOTOR (STAR 20B-LIKE)	SOLID ROCKET MOTOR CASE INSULATION	A3.B3.C1.D3.E3.F1.G2	MAIN PROPULSION	MAIN PROPELLANT STORAGE & DISTRIBUTION	MAIN PROPELLANT STORAGE AND CONTAINMENT
1.1.1.02.03.03	SOLID ROCKET MOTOR (STAR 20B-LIKE)	SOLID PROPELLANT (EXPENDED)	A3.B3.C1.D3.E3.F7.G1	MAIN PROPULSION	SUPPLY MAIN ON-BOARD REACTION MASS	SUPPLY MAIN REACTION MASS
1.1.1.02.03.04	SOLID ROCKET MOTOR (STAR 20B-LIKE)	SOLID PROPELLANT (RESIDUAL)	A3.B3.C1.D3.E3.F7.G2	MAIN PROPULSION	SUPPLY MAIN ON-BOARD REACTION MASS	SUPPLY MAIN REACTION MASS BIAS/MARGIN
1.1.1.02.03.05	SOLID ROCKET MOTOR (STAR 20B-LIKE)	EXHAUST NOZZLE	A3.B3.C1.D3.E3.F5.G5	MAIN PROPULSION	MAIN THRUST GENERATION/POWER PLANT FUNCTION	MAIN PROPULSION NOZZLE/EXHAUST GAS MANAGEMENT (EXPULSION/EXPANSION OF COMBUSTI
1.1.1.02.03.06	SOLID ROCKET MOTOR (STAR 20B-LIKE)	SOLID ROCKET MOTOR MAIN CHAMBER IGNITER SYSTEM COMPONENTS	A3.B3.C1.D3.E3.F5.G3	MAIN PROPULSION	MAIN THRUST GENERATION/POWER PLANT FUNCTION	STARTING/IGNITION FOR MAIN PROPULSION
1.1.1.02.03.07	SOLID ROCKET MOTOR (STAR 20B-LIKE)	SENSORS (CHAMBER PRESSURE)	A3.B3.C1.D3.E3.F6.G5	MAIN PROPULSION	MAIN PROPELLANT FLOW PATH MANAGEMENT	MAIN PROPULSION SYSTEM SENSOR DATA COLLECTION AND SIGNAL CONDITIONING
1.1.1.02.04.01	ELECTRICAL POWER DISTRIBUTION	POWER CABLING	A3.B3.C1.D3.E5.F3.G2	ELECTRICAL POWER GENERATION, CONTROL, AND DISTR	ELECTRICAL POWER DISTRIBUTION	DISTRIBUTE ELECTRICAL POWER
1.1.1.02.05.01	VENT	OUTLETS AND VENTS (ON FWD INTERSTAGE)	A3.B3.C1.D3.E8.F3.G3	ENVIRONMENTAL AND ACTIVE THERMAL CONTROL	VEHICLE ENVIRONMENTAL PRESSURIZATION/MOISTURE CONTROL	VEHICLE STRUCTURE VENTING
1.1.1.02.06.01	COMMAND & CONTROL	CABLING AND WIRING	A3.B3.C1.D3.E9.F1.G2	COMMAND AND DATA MANAGEMENT	VEH SYSTEMS COMMAND & DATA DISTRIBUTION/SIGNAL CONDITIONING	VEH SYSTEMS SIGNAL CONVERSION, AMPLIFICATION & DISTRIBUTION
1.1.1.02.07.01	SEPARATION	MECHANICAL SEPARATION COMPONENTS (E.G., SPRING SETS)	A3.B3.C1.D3.E15.F1.G1	STAGE/ELEMENT SEPARATION	SEPARATING WITHOUT EXPLOSIVES	ROUTINE MECHANICAL STAGE/ELEMENT SEPARATION/JETTISON (E.G., SPRING SETS)
1.1.1.02.08.01	RAIL (FLT HALF)	LAUNCH RAIL INTERFACE STRUCTURAL/MECHANICAL EQUIPMENT (FLIGHT HALF)	A3.B3.C1.D3.E16.F2.G1	LAUNCH/TAKEOFF AND LANDING SUPPORT	GROUND LAUNCH ASSIST	PASSIVE GROUND LAUNCH RAIL INTERFACING (FLIGHT HALF FUNCTION)
1.1.1.03.01.01	STRUCTURE	AFT INTERSTAGE STRUCTURE (REINFORCED FOR STABILIZER FINS)	A3.B3.C1.D4.E1.F5.G1	STRUCTURAL CONTAINMENT AND SUPPORT	CONNECT AND ATTACH ELEMENTS	FLIGHT-TO-FLIGHT STRUCTURAL CONNECTION AND ATTACHMENT
1.1.1.03.01.02	STRUCTURE	SYSTEMS TUNNEL COVER/FAIRING	A3.B3.C1.D4.E1.F2.G1	STRUCTURAL CONTAINMENT AND SUPPORT	NON-BODY/FRAMEWORK FUNCTIONS - ATTACHMENT TO BODY/FRAMEWORK	NON-BODY/FRAMEWORK COMPARTMENTALIZATION
1.1.1.03.01.03	STRUCTURE	FWD INTERSTAGE STRUCTURE	A3.B3.C1.D4.E1.F5.G1	STRUCTURAL CONTAINMENT AND SUPPORT	CONNECT AND ATTACH ELEMENTS	FLIGHT-TO-FLIGHT STRUCTURAL CONNECTION AND ATTACHMENT
1.1.1.03.01.04	STRUCTURE	FWD INTERSTAGE ACCESS PANELS	A3.B3.C1.D4.E1.F2.G1	STRUCTURAL CONTAINMENT AND SUPPORT	NON-BODY/FRAMEWORK FUNCTIONS - ATTACHMENT TO BODY/FRAMEWORK	NON-BODY/FRAMEWORK COMPARTMENTALIZATION
1.1.1.03.01.05	STRUCTURE	AFT INTERSTAGE ACCESS PANELS	A3.B3.C1.D4.E1.F2.G1	STRUCTURAL CONTAINMENT AND SUPPORT	NON-BODY/FRAMEWORK FUNCTIONS - ATTACHMENT TO BODY/FRAMEWORK	NON-BODY/FRAMEWORK COMPARTMENTALIZATION
1.1.1.03.01.06	STRUCTURE	THIRD/FOURTH STAGE ADAPTER STRUCTURE	A3.B3.C1.D4.E1.F5.G1	STRUCTURAL CONTAINMENT AND SUPPORT	CONNECT AND ATTACH ELEMENTS	FLIGHT-TO-FLIGHT STRUCTURAL CONNECTION AND ATTACHMENT
1.1.1.03.02.01	STABILIZATION	DE-SPIN/YO-YO COMPONENTS/ASSEMBLY	A3.B3.C1.D4.E2.F4.G1	VEHICLE STABILITY AND CONTROL	VEHICLE SPIN STABILIZATION (AND/OR DE-SPIN)	PROPULSIVE VEHICLE SPIN-UP (AND/OR DE-SPIN)
1.1.1.03.03.01	SOLID ROCKET MOTOR (STAR 15G-LIKE)	SOLID ROCKET MOTOR CASE STRUCTURE	A3.B3.C1.D4.E3.F1.G2	MAIN PROPULSION	MAIN PROPELLANT STORAGE & DISTRIBUTION	MAIN PROPELLANT STORAGE AND CONTAINMENT
1.1.1.03.03.02	SOLID ROCKET MOTOR (STAR 15G-LIKE)	SOLID ROCKET MOTOR CASE INSULATION	A3.B3.C1.D4.E3.F1.G2	MAIN PROPULSION	MAIN PROPELLANT STORAGE & DISTRIBUTION	MAIN PROPELLANT STORAGE AND CONTAINMENT
1.1.1.03.03.03	SOLID ROCKET MOTOR (STAR 15G-LIKE)	SOLID PROPELLANT (EXPENDED)	A3.B3.C1.D4.E3.F7.G1	MAIN PROPULSION	SUPPLY MAIN ON-BOARD REACTION MASS	SUPPLY MAIN REACTION MASS
1.1.1.03.03.04	SOLID ROCKET MOTOR (STAR 15G-LIKE)	SOLID PROPELLANT (RESIDUAL)	A3.B3.C1.D4.E3.F7.G2	MAIN PROPULSION	SUPPLY MAIN ON-BOARD REACTION MASS	SUPPLY MAIN REACTION MASS BIAS/MARGIN
1.1.1.03.03.05	SOLID ROCKET MOTOR (STAR 15G-LIKE)	EXHAUST NOZZLE	A3.B3.C1.D4.E3.F5.G5	MAIN PROPULSION	MAIN THRUST GENERATION/POWER PLANT FUNCTION	MAIN PROPULSION NOZZLE/EXHAUST GAS MANAGEMENT (EXPULSION/EXPANSION OF COMBUSTI
1.1.1.03.03.06	SOLID ROCKET MOTOR (STAR 15G-LIKE)	SOLID ROCKET MOTOR MAIN CHAMBER IGNITER SYSTEM COMPONENTS	A3.B3.C1.D4.E3.F5.G3	MAIN PROPULSION	MAIN THRUST GENERATION/POWER PLANT FUNCTION	STARTING/IGNITION FOR MAIN PROPULSION
1.1.1.03.03.07	SOLID ROCKET MOTOR (STAR 15G-LIKE)	SENSORS (CHAMBER PRESSURE)	A3.B3.C1.D4.E3.F6.G5	MAIN PROPULSION	MAIN PROPELLANT FLOW PATH MANAGEMENT	MAIN PROPULSION SYSTEM SENSOR DATA COLLECTION AND SIGNAL CONDITIONING
1.1.1.03.04.01	ELECTRICAL POWER	AVIONICS DC BATTERY	A3.B3.C1.D4.E5.F1.G6	ELECTRICAL POWER GENERATION, CONTROL, AND DISTR	ENERGY/POWER SOURCE (FOR CENTRALIZED ELECTRIC POWER TO MORE THAN	ELECTRO-CHEMICAL ENERGY STORAGE (PROVIDE BATTERY-TYPE PRIMARY VEH ELECTRICAL POWER
1.1.1.03.04.02	ELECTRICAL POWER	DC POWER DISTRIBUTION UNIT	A3.B3.C1.D4.E5.F3.G1	ELECTRICAL POWER GENERATION, CONTROL, AND DISTR	ELECTRICAL POWER DISTRIBUTION	POWER CONTROL AND SWITCHING
1.1.1.03.04.03	ELECTRICAL POWER	ELECTRIC POWER HARNESSES, CABLES, WIRING	A3.B3.C1.D4.E5.F3.G2	ELECTRICAL POWER GENERATION, CONTROL, AND DISTR	ELECTRICAL POWER DISTRIBUTION	DISTRIBUTE ELECTRICAL POWER
1.1.1.03.05.01	VENT	OUTLETS & VENTS	A3.B3.C1.D4.E8.F3.G3	ENVIRONMENTAL AND ACTIVE THERMAL CONTROL	VEHICLE ENVIRONMENTAL PRESSURIZATION/MOISTURE CONTROL	VEHICLE STRUCTURE VENTING
1.1.1.03.06.01	COMMAND & CONTROL	SIGNAL HARNESSES, CABLES, WIRING	A3.B3.C1.D4.E9.F1.G2	COMMAND AND DATA MANAGEMENT	VEH SYSTEMS COMMAND & DATA DISTRIBUTION/SIGNAL CONDITIONING	VEH SYSTEMS SIGNAL CONVERSION, AMPLIFICATION & DISTRIBUTION
1.1.1.03.07.01	COMMUNICATIONS	TM ENCODER UNIT	A3.B3.C1.D4.E10.F1.G2	COMMUNICATIONS AND TRACKING	VEH LONG-RANGE VOICE AND DATA CONNECTIVITY	LONG-RANGE VOICE AND DATA RADIOFREQUENCY (RF) SIGNAL PROCESSING AND CONVERSION
1.1.1.03.07.05	COMMUNICATIONS	S-BAND ANTENNA 1	A3.B3.C1.D4.E10.F1.G1	COMMUNICATIONS AND TRACKING	VEH LONG-RANGE VOICE AND DATA CONNECTIVITY	LONG-RANGE VOICE AND DATA RADIOFREQUENCY (RF) RADIATION/SIGNAL COLLECTION
1.1.1.03.07.05	COMMUNICATIONS	C-BAND RADAR BEACON ANTENNA 1	A3.B3.C1.D4.E10.F1.G1	COMMUNICATIONS AND TRACKING	VEH LONG-RANGE VOICE AND DATA CONNECTIVITY	LONG-RANGE VOICE AND DATA RADIOFREQUENCY (RF) RADIATION/SIGNAL COLLECTION
1.1.1.03.07.06	COMMUNICATIONS	S-BAND ANTENNA 2	A3.B3.C1.D4.E10.F1.G1	COMMUNICATIONS AND TRACKING	VEH LONG-RANGE VOICE AND DATA CONNECTIVITY	LONG-RANGE VOICE AND DATA RADIOFREQUENCY (RF) RADIATION/SIGNAL COLLECTION
1.1.1.03.07.06	COMMUNICATIONS	C-BAND RADAR BEACON ANTENNA 2	A3.B3.C1.D4.E10.F1.G1	COMMUNICATIONS AND TRACKING	VEH LONG-RANGE VOICE AND DATA CONNECTIVITY	LONG-RANGE VOICE AND DATA RADIOFREQUENCY (RF) RADIATION/SIGNAL COLLECTION
1.1.1.03.07.07	COMMUNICATIONS	S-BAND TRANSPONDER	A3.B3.C1.D4.E10.F1.G2	COMMUNICATIONS AND TRACKING	VEH LONG-RANGE VOICE AND DATA CONNECTIVITY	LONG-RANGE VOICE AND DATA RADIOFREQUENCY (RF) SIGNAL PROCESSING AND CONVERSION
1.1.1.03.07.07	COMMUNICATIONS	C-BAND RADAR BEACON UNIT	A3.B3.C1.D4.E10.F1.G2	COMMUNICATIONS AND TRACKING	VEH LONG-RANGE VOICE AND DATA CONNECTIVITY	LONG-RANGE VOICE AND DATA RADIOFREQUENCY (RF) SIGNAL PROCESSING AND CONVERSION
1.1.1.03.08.02	NAVIGATION	GPS/L-BAND ANTENNA 1	A3.B3.C1.D4.E11.F2.G2	GUIDANCE AND NAVIGATION (G&N)	OFF-BOARD STATE DETERMINATION	SPACE-BASED STATE DETERMINATION (E.G., GLOBAL POSITIONING SATELLITE NETWORK)
1.1.1.03.08.02	NAVIGATION	ATTITUDE CONTROL DRIVER/SIGNAL CONDITIONER	A3.B3.C1.D4.E9.F1.G2	COMMAND AND DATA MANAGEMENT	VEH SYSTEMS COMMAND & DATA DISTRIBUTION/SIGNAL CONDITIONING	VEH SYSTEMS SIGNAL CONVERSION, AMPLIFICATION & DISTRIBUTION
1.1.1.03.08.03	NAVIGATION	GPS/L-BAND ANTENNA 2	A3.B3.C1.D4.E11.F2.G2	GUIDANCE AND NAVIGATION (G&N)	OFF-BOARD STATE DETERMINATION	SPACE-BASED STATE DETERMINATION (E.G., GLOBAL POSITIONING SATELLITE NETWORK)
1.1.1.03.08.04	NAVIGATION	GPS ELECTRONICS (LNA/COMB FILTER/RECEIVER)	A3.B3.C1.D4.E11.F2.G2	GUIDANCE AND NAVIGATION (G&N)	OFF-BOARD STATE DETERMINATION	SPACE-BASED STATE DETERMINATION (E.G., GLOBAL POSITIONING SATELLITE NETWORK)
1.1.1.03.08.05	NAVIGATION	INS UNIT	A3.B3.C1.D4.E11.F1.G2	GUIDANCE AND NAVIGATION (G&N)	ON-BOARD STATE DETERMINATION	ON-BOARD VEHICLE NAVIGATION STATE DETERMINATION
1.1.1.03.09.01	FLIGHT TERMINATION	UHF FLT TERMINATION ANTENNA 1	A3.B3.C1.D4.E12.F2.G1	FLIGHT TERMINATION AND ABORT MODING	DESTRUCTIVE FLIGHT TERMINATION	ORDNANCE DESTRUCT
1.1.1.03.09.02	FLIGHT TERMINATION	UHF FLT TERMINATION ANTENNA 2	A3.B3.C1.D4.E12.F2.G1	FLIGHT TERMINATION AND ABORT MODING	DESTRUCTIVE FLIGHT TERMINATION	ORDNANCE DESTRUCT
1.1.1.03.09.03	FLIGHT TERMINATION	FLT TERMINATION RECEIVER 1	A3.B3.C1.D4.E12.F2.G1	FLIGHT TERMINATION AND ABORT MODING	DESTRUCTIVE FLIGHT TERMINATION	ORDNANCE DESTRUCT
1.1.1.03.09.04	FLIGHT TERMINATION	FLT TERMINATION RECEIVER 2	A3.B3.C1.D4.E12.F2.G1	FLIGHT TERMINATION AND ABORT MODING	DESTRUCTIVE FLIGHT TERMINATION	ORDNANCE DESTRUCT
1.1.1.03.09.05	FLIGHT TERMINATION	FLT TERMINATION BATTERY 1	A3.B3.C1.D4.E12.F2.G1	FLIGHT TERMINATION AND ABORT MODING	DESTRUCTIVE FLIGHT TERMINATION	ORDNANCE DESTRUCT
1.1.1.03.09.06	FLIGHT TERMINATION	FLT TERMINATION BATTERY 2	A3.B3.C1.D4.E12.F2.G1	FLIGHT TERMINATION AND ABORT MODING	DESTRUCTIVE FLIGHT TERMINATION	ORDNANCE DESTRUCT
1.1.1.03.09.07	FLIGHT TERMINATION	FLT TERMINATION SYSTEM ORDNANCE DRIVER UNIT	A3.B3.C1.D4.E12.F2.G1	FLIGHT TERMINATION AND ABORT MODING	DESTRUCTIVE FLIGHT TERMINATION	ORDNANCE DESTRUCT
1.1.1.03.09.08	FLIGHT TERMINATION	DESTRUCT ORDNANCE (THRID AND FOURTH STG)	A3.B3.C1.D4.E12.F2.G1	FLIGHT TERMINATION AND ABORT MODING	DESTRUCTIVE FLIGHT TERMINATION	ORDNANCE DESTRUCT
1.1.1.03.10.01	SEPARATION	MECHANICAL SEPARATION COMPONENTS/ASSEMBLY	A3.B3.C1.D4.E15.F1.G1	STAGE/ELEMENT SEPARATION	SEPARATING WITHOUT EXPLOSIVES	ROUTINE MECHANICAL STAGE/ELEMENT SEPARATION/JETTISON (E.G., SPRING SETS)
1.1.1.04.01.01	STRUCTURE	ADAPTER RING STRUCTURE	A3.B3.C1.D4.E1.F5.G1	STRUCTURAL CONTAINMENT AND SUPPORT	CONNECT AND ATTACH ELEMENTS	FLIGHT-TO-FLIGHT STRUCTURAL CONNECTION AND ATTACHMENT
1.1.1.04.02.01	ATTITUDE CONTROL	REACTION CONTROL JETS/MODULES	A3.B3.C1.D4.E2.F3.G12	VEHICLE STABILITY AND CONTROL	VEHICLE REACTION CONTROL AND STABILIZATION	REACTION THRUST GENERATION
1.1.1.04.02.02	ATTITUDE CONTROL	REACTION CONTROL PROPELLANT STORAGE AND DISTRIBUTION	A3.B3.C1.D4.E2.F3.G2	VEHICLE STABILITY AND CONTROL	VEHICLE REACTION CONTROL AND STABILIZATION	REACTION CONTROL PROPELLANT STORAGE AND CONTAINMENT
1.1.1.04.03.01	SOLID ROCKET MOTOR (COI MOTOR)	SOLID ROCKET MOTOR CASE STRUCTURE	A3.B3.C1.D4.E3.F1.G2	MAIN PROPULSION	MAIN PROPELLANT STORAGE & DISTRIBUTION	MAIN PROPELLANT STORAGE AND CONTAINMENT
1.1.1.04.03.02	SOLID ROCKET MOTOR (COI MOTOR)	SOLID ROCKET MOTOR CASE INSULATION	A3.B3.C1.D4.E3.F1.G2	MAIN PROPULSION	MAIN PROPELLANT STORAGE & DISTRIBUTION	MAIN PROPELLANT STORAGE AND CONTAINMENT
1.1.1.04.03.03	SOLID ROCKET MOTOR (COI MOTOR)	SOLID PROPELLANT (EXPENDED)	A3.B3.C1.D4.E3.F7.G1	MAIN PROPULSION	SUPPLY MAIN ON-BOARD REACTION MASS	SUPPLY MAIN REACTION MASS
1.1.1.04.03.04	SOLID ROCKET MOTOR (COI MOTOR)	SOLID PROPELLANT (RESIDUAL)	A3.B3.C1.D4.E3.F7.G2	MAIN PROPULSION	SUPPLY MAIN ON-BOARD REACTION MASS	SUPPLY MAIN REACTION MASS BIAS/MARGIN
1.1.1.04.03.05	SOLID ROCKET MOTOR (COI MOTOR)	EXHAUST NOZZLE	A3.B3.C1.D4.E3.F5.G5	MAIN PROPULSION	MAIN THRUST GENERATION/POWER PLANT FUNCTION	MAIN PROPULSION NOZZLE/EXHAUST GAS MANAGEMENT (EXPULSION/EXPANSION OF COMBUSTI
1.1.1.04.03.06	SOLID ROCKET MOTOR (COI MOTOR)	SOLID ROCKET MOTOR MAIN CHAMBER IGNITER SYSTEM COMPONENTS	A3.B3.C1.D4.E3.F5.G3	MAIN PROPULSION	MAIN THRUST GENERATION/POWER PLANT FUNCTION	STARTING/IGNITION FOR MAIN PROPULSION
1.1.1.04.04.01	ELECTRICAL POWER DISTRIBUTION	AVIONICS DC BATTERY	A3.B3.C1.D4.E5.F1.G6	ELECTRICAL POWER GENERATION, CONTROL, AND DISTR	ENERGY/POWER SOURCE (FOR CENTRALIZED ELECTRIC POWER TO MORE THAN	ELECTRO-CHEMICAL ENERGY STORAGE (PROVIDE BATTERY-TYPE PRIMARY VEH ELECTRICAL POWER
1.1.1.04.04.02	ELECTRICAL POWER DISTRIBUTION	DC POWER DISTRIBUTION UNIT	A3.B3.C1.D4.E5.F3.G1	ELECTRICAL POWER GENERATION, CONTROL, AND DISTR	ELECTRICAL POWER DISTRIBUTION	POWER CONTROL AND SWITCHING
1.1.1.04.04.03	ELECTRICAL POWER DISTRIBUTION	POWER CABLES AND WIRING	A3.B3.C1.D4.E5.F3.G2	ELECTRICAL POWER GENERATION, CONTROL, AND DISTR	ELECTRICAL POWER DISTRIBUTION	DISTRIBUTE ELECTRICAL POWER
1.1.1.04.05.01	COMMAND & CONTROL	FLIGHT COMPUTER	A3.B3.C1.D4.E9.F2.G1	COMMAND AND DATA MANAGEMENT	VEH SYSTEMS COMMAND AND DATA PROCESSING	FLIGHT CRITICAL COMMAND AND DATA PROCESSING
1.1.1.04.05.02	COMMAND & CONTROL	FLIGHT CRITICAL SOFTWARE LOAD	A3.B3.C1.D4.E9.F2.G1	COMMAND AND DATA MANAGEMENT	VEH SYSTEMS COMMAND AND DATA PROCESSING	FLIGHT CRITICAL COMMAND AND DATA PROCESSING
1.1.1.04.05.03	COMMAND & CONTROL	SIGNAL HARNESSES, CABLES, WIRING	A3.B3.C1.D4.E9.F1.G2	COMMAND AND DATA MANAGEMENT	VEH SYSTEMS COMMAND & DATA DISTRIBUTION/SIGNAL CONDITIONING	VEH SYSTEMS SIGNAL CONVERSION, AMPLIFICATION & DISTRIBUTION
1.1.1.04.05.04	VENT	OUTLETS & VENTS	A3.B3.C1.D4.E8.F3.G3	ENVIRONMENTAL AND ACTIVE THERMAL CONTROL	VEHICLE ENVIRONMENTAL PRESSURIZATION/MOISTURE CONTROL	VEHICLE STRUCTURE VENTING
1.1.1.04.06.01	NAVIGATION	INS UNIT	A3.B3.C1.D4.E11.F2.G2	GUIDANCE AND NAVIGATION (G&N)	OFF-BOARD STATE DETERMINATION	SPACE-BASED STATE DETERMINATION (E.G., GLOBAL POSITIONING SATELLITE NETWORK)
1.1.1.04.06.02	NAVIGATION	ATTITUDE CONTROL DRIVER/SIGNAL CONDITIONER	A3.B3.C1.D4.E9.F1.G2	COMMAND AND DATA MANAGEMENT	VEH SYSTEMS COMMAND & DATA DISTRIBUTION/SIGNAL CONDITIONING	VEH SYSTEMS SIGNAL CONVERSION, AMPLIFICATION & DISTRIBUTION
1.1.1.04.06.03	NAVIGATION	GPS/L-BAND ANTENNA 1	A3.B3.C1.D4.E11.F2.G2	GUIDANCE AND NAVIGATION (G&N)	OFF-BOARD STATE DETERMINATION	SPACE-BASED STATE DETERMINATION (E.G., GLOBAL POSITIONING SATELLITE NETWORK)
1.1.1.04.06.04	NAVIGATION	GPS/L-BAND ANTENNA 2	A3.B3.C1.D4.E11.F2.G2	GUIDANCE AND NAVIGATION (G&N)	OFF-BOARD STATE DETERMINATION	SPACE-BASED STATE DETERMINATION (E.G., GLOBAL POSITIONING SATELLITE NETWORK)
1.1.1.04.06.05	NAVIGATION	GPS ELECTRONICS UNIT (LNA/COMB)	A3.B3.C1.D4.E11.F2.G2	GUIDANCE AND NAVIGATION (G&N)	OFF-BOARD STATE DETERMINATION	SPACE-BASED STATE DETERMINATION (E.G., GLOBAL POSITIONING SATELLITE NETWORK)
1.1.1.05.01.01	STRUCTURE	FAIRING CONE SRTUCTURE	A3.B3.C1.D7.E1.F3.G1	STRUCTURAL CONTAINMENT AND SUPPORT	ENCLOSE PAYLOAD	ENCLOSE PAYLOAD
1.1.1.05.02.01	THERMAL	ABLATIVE LAYER/COATING	A3.B3.C1.D7.E7.F1.G1	THERMAL PROTECTION	PASSIVE THERMAL PROTECTION	ABLATIVE PROTECTION
1.1.1.05.02.02	THERMAL	INTERNAL THERMAL/ACOUSTIC INSULATION	A3.B3.C1.D7.E7.F2.G1	THERMAL PROTECTION	PERMANENT THERMAL PROTECTION	INSULATE "HOT STRUCTURE" INTERIOR
1.1.1.05.03.01	VENT	OUTLETS AND VENTS	A3.B3.C1.D7.E8.F3.G3	ENVIRONMENTAL AND ACTIVE THERMAL CONTROL	VEHICLE ENVIRONMENTAL PRESSURIZATION/MOISTURE CONTROL	VEHICLE STRUCTURE VENTING
1.1.1.05.04.01	SEPARATION	FAIRING SEPARATION MECHANISM (NON-PYRO)	A3.B3.C1.D7.E15.F1.G1	STAGE/ELEMENT SEPARATION	SEPARATING WITHOUT EXPLOSIVES	ROUTINE MECHANICAL STAGE/ELEMENT SEPARATION/JETTISON (E.G., SPRING SETS)

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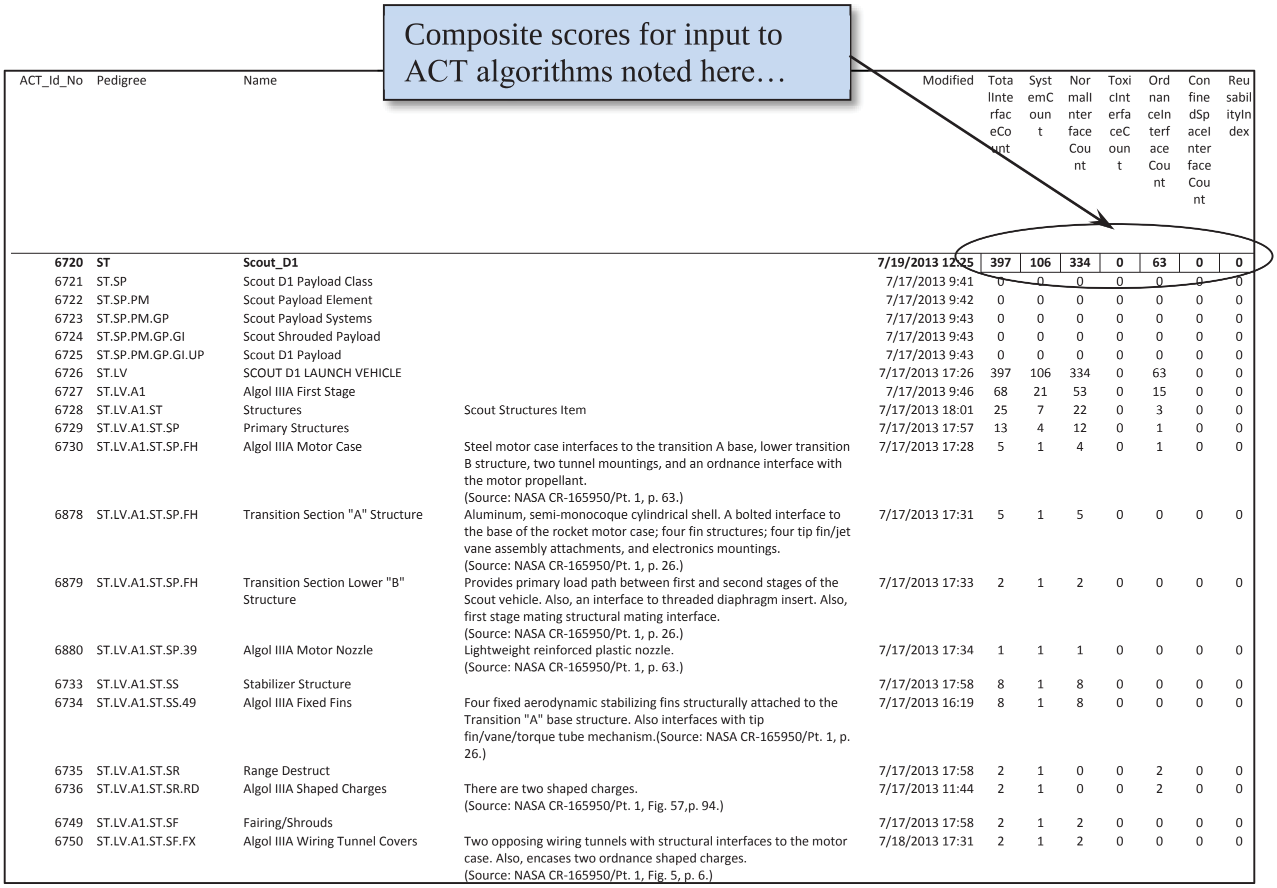
APPENDIX G. SAMPLE/PARTIAL OUTPUT OF SCOUT VEHICLE ANCHOR IN ACT PROTOTYPE ARCHITECTURAL DEFINITION TOOL



Composite scores for input to ACT algorithms noted here…

ACT_Id_No	Pedigree	Name		Modified	TotalInterfaceCount	SystemCount	NormalInterfaceCount	ToxicInterfaceCount	OrdnanceInterfaceCount	ConfinedSpaceInterfaceCount	ReusabilityIndex
6720	**ST**	**Scout_D1**		**7/19/2013 12:25**	**397**	**106**	**334**	**0**	**63**	**0**	**0**
6721	ST.SP	Scout D1 Payload Class		7/17/2013 9:41	0	0	0	0	0	0	0
6722	ST.SP.PM	Scout Payload Element		7/17/2013 9:42	0	0	0	0	0	0	0
6723	ST.SP.PM.GP	Scout Payload Systems		7/17/2013 9:43	0	0	0	0	0	0	0
6724	ST.SP.PM.GP.GI	Scout Shrouded Payload		7/17/2013 9:43	0	0	0	0	0	0	0
6725	ST.SP.PM.GP.GI.UP	Scout D1 Payload		7/17/2013 9:43	0	0	0	0	0	0	0
6726	ST.LV	SCOUT D1 LAUNCH VEHICLE		7/17/2013 17:26	397	106	334	0	63	0	0
6727	ST.LV.A1	Algol IIIA First Stage		7/17/2013 9:46	68	21	53	0	15	0	0
6728	ST.LV.A1.ST	Structures	Scout Structures Item	7/17/2013 18:01	25	7	22	0	3	0	0
6729	ST.LV.A1.ST.SP	Primary Structures		7/17/2013 17:57	13	4	12	0	1	0	0
6730	ST.LV.A1.ST.SP.FH	Algol IIIA Motor Case	Steel motor case interfaces to the transition A base, lower transition B structure, two tunnel mountings, and an ordnance interface with the motor propellant. (Source: NASA CR-165950/Pt. 1, p. 63.)	7/17/2013 17:28	5	1	4	0	1	0	0
6878	ST.LV.A1.ST.SP.FH	Transition Section "A" Structure	Aluminum, semi-monocoque cylindrical shell. A bolted interface to the base of the rocket motor case; four fin structures; four tip fin/jet vane assembly attachments, and electronics mountings. (Source: NASA CR-165950/Pt. 1, p. 26.)	7/17/2013 17:31	5	1	5	0	0	0	0
6879	ST.LV.A1.ST.SP.FH	Transition Section Lower "B" Structure	Provides primary load path between first and second stages of the Scout vehicle. Also, an interface to threaded diaphragm insert. Also, first stage mating structural mating interface. (Source: NASA CR-165950/Pt. 1, p. 26.)	7/17/2013 17:33	2	1	2	0	0	0	0
6880	ST.LV.A1.ST.SP.39	Algol IIIA Motor Nozzle	Lightweight reinforced plastic nozzle. (Source: NASA CR-165950/Pt. 1, p. 63.)	7/17/2013 17:34	1	1	1	0	0	0	0
6733	ST.LV.A1.ST.SS	Stabilizer Structure		7/17/2013 17:58	8	1	8	0	0	0	0
6734	ST.LV.A1.ST.SS.49	Algol IIIA Fixed Fins	Four fixed aerodynamic stabilizing fins structurally attached to the Transition "A" base structure. Also interfaces with tip fin/vane/torque tube mechanism.(Source: NASA CR-165950/Pt. 1, p. 26.)	7/17/2013 16:19	8	1	8	0	0	0	0
6735	ST.LV.A1.ST.SR	Range Destruct		7/17/2013 17:58	2	1	0	0	2	0	0
6736	ST.LV.A1.ST.SR.RD	Algol IIIA Shaped Charges	There are two shaped charges. (Source: NASA CR-165950/Pt. 1, Fig. 57,p. 94.)	7/17/2013 11:44	2	1	0	0	2	0	0
6749	ST.LV.A1.ST.SF	Fairing/Shrouds		7/17/2013 17:58	2	1	2	0	0	0	0
6750	ST.LV.A1.ST.SF.FX	Algol IIIA Wiring Tunnel Covers	Two opposing wiring tunnels with structural interfaces to the motor case. Also, encases two ordnance shaped charges. (Source: NASA CR-165950/Pt. 1, Fig. 5, p. 6.)	7/18/2013 17:31	2	1	2	0	0	0	0

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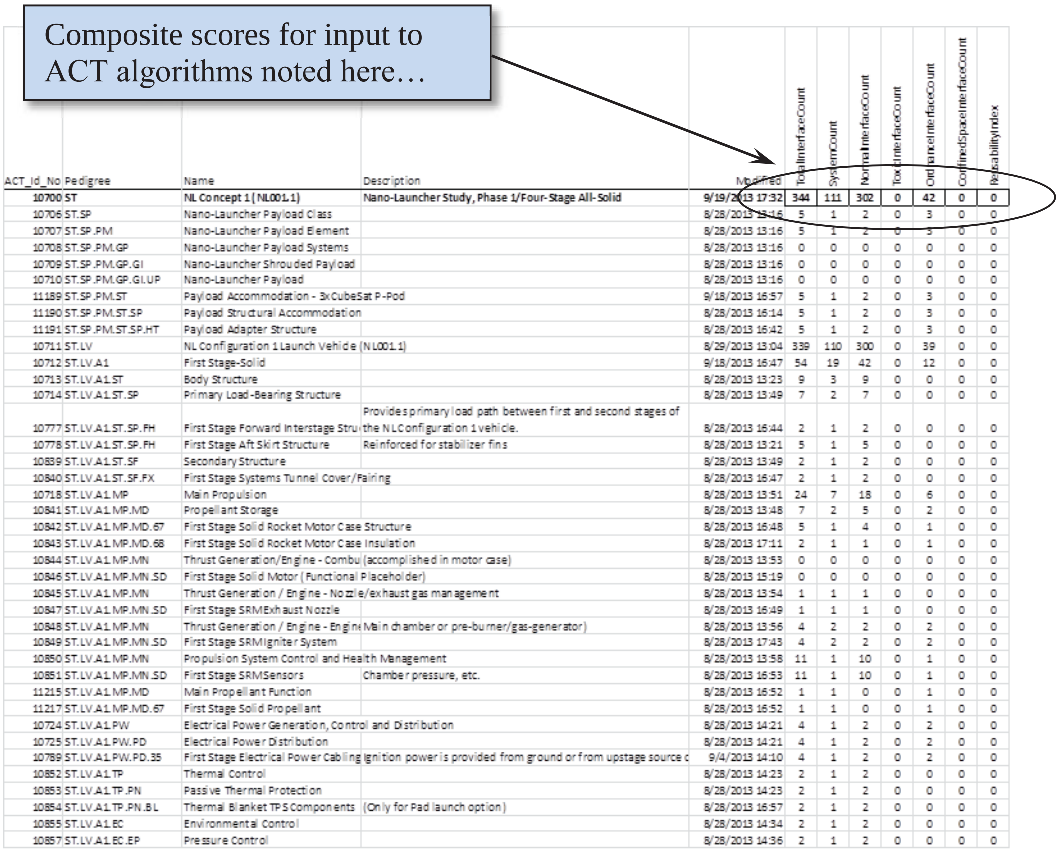
APPENDIX H. SAMPLE/PARTIAL OUTPUT OF NL001 ALL-SOLID IN ACT PROTOTYPE ARCHITECTURAL DEFINITION TOOL (NL PHASE I ANALYSIS)



Composite scores for input to ACT algorithms noted here…

ACT_Id_No	Pedigree	Name	Description	Modified	TotalInterfaceCount	SystemCount	NormalInterfaceCount	ToxicInterfaceCount	OrdnanceInterfaceCount	ConfinedSpaceInterfaceCount	ReusabilityIndex
10700	**ST**	**NL Concept 1 (NL001.1)**	**Nano-Launcher Study, Phase 1/Four-Stage All-Solid**	**9/19/2013 17:32**	**344**	**111**	**302**	**0**	**42**	**0**	**0**
10706	ST.SP	Nano-Launcher Payload Class		8/28/2013 13:16	5	1	2	0	3	0	0
10707	ST.SP.PM	Nano-Launcher Payload Element		8/28/2013 13:16	5	1	2	0	3	0	0
10708	ST.SP.PM.GP	Nano-Launcher Payload Systems		8/28/2013 13:16	0	0	0	0	0	0	0
10709	ST.SP.PM.GP.GI	Nano-Launcher Shrouded Payload		8/28/2013 13:16	0	0	0	0	0	0	0
10710	ST.SP.PM.GP.GI.UP	Nano-Launcher Payload		8/28/2013 13:16	0	0	0	0	0	0	0
11189	ST.SP.PM.ST	Payload Accommodation - 3xCubeSat P-Pod		9/18/2013 16:57	5	1	2	0	3	0	0
11190	ST.SP.PM.ST.SP	Payload Structural Accommodation		8/28/2013 16:14	5	1	2	0	3	0	0
11191	ST.SP.PM.ST.SP.HT	Payload Adapter Structure		8/28/2013 16:42	5	1	2	0	3	0	0
10711	ST.LV	NL Configuration 1 Launch Vehicle (NL001.1)		8/29/2013 13:04	339	110	300	0	39	0	0
10712	ST.LV.A1	First Stage-Solid		9/18/2013 16:47	54	19	42	0	12	0	0
10713	ST.LV.A1.ST	Body Structure		8/28/2013 13:23	9	3	9	0	0	0	0
10714	ST.LV.A1.ST.SP	Primary Load-Bearing Structure		8/28/2013 13:49	7	2	7	0	0	0	0
10777	ST.LV.A1.ST.SP.FH	First Stage Forward Interstage Stru	Provides primary load path between first and second stages of the NL Configuration 1 vehicle.	8/28/2013 16:44	2	1	2	0	0	0	0
10778	ST.LV.A1.ST.SP.FH	First Stage Aft Skirt Structure	Reinforced for stabilizer fins	8/28/2013 13:21	5	1	5	0	0	0	0
10839	ST.LV.A1.ST.SF	Secondary Structure		8/28/2013 13:49	2	1	2	0	0	0	0
10840	ST.LV.A1.ST.SF.FX	First Stage Systems Tunnel Cover/Fairing		8/28/2013 16:47	2	1	2	0	0	0	0
10718	ST.LV.A1.MP	Main Propulsion		8/28/2013 13:51	24	7	18	0	6	0	0
10841	ST.LV.A1.MP.MD	Propellant Storage		8/28/2013 13:48	7	2	5	0	2	0	0
10842	ST.LV.A1.MP.MD.67	First Stage Solid Rocket Motor Case Structure		8/28/2013 16:48	5	1	4	0	1	0	0
10843	ST.LV.A1.MP.MD.68	First Stage Solid Rocket Motor Case Insulation		8/28/2013 17:11	2	1	1	0	1	0	0
10844	ST.LV.A1.MP.MN	Thrust Generation/Engine - Combu	(accomplished in motor case)	8/28/2013 13:53	0	0	0	0	0	0	0
10846	ST.LV.A1.MP.MN.SD	First Stage Solid Motor (Functional Placeholder)		8/28/2013 15:19	0	0	0	0	0	0	0
10845	ST.LV.A1.MP.MN	Thrust Generation / Engine - Nozzle/exhaust gas management		8/28/2013 13:54	1	1	1	0	0	0	0
10847	ST.LV.A1.MP.MN.SD	First Stage SRM Exhaust Nozzle		8/28/2013 16:49	1	1	1	0	0	0	0
10848	ST.LV.A1.MP.MN	Thrust Generation / Engine - Engin	Main chamber or pre-burner/gas-generator)	8/28/2013 13:56	4	2	2	0	2	0	0
10849	ST.LV.A1.MP.MN.SD	First Stage SRM Igniter System		8/28/2013 17:43	4	2	2	0	2	0	0
10850	ST.LV.A1.MP.MN	Propulsion System Control and Health Management		8/28/2013 13:58	11	1	10	0	1	0	0
10851	ST.LV.A1.MP.MN.SD	First Stage SRM Sensors	Chamber pressure, etc.	8/28/2013 16:53	11	1	10	0	1	0	0
11215	ST.LV.A1.MP.MD	Main Propellant Function		8/28/2013 16:52	1	1	0	0	1	0	0
11217	ST.LV.A1.MP.MD.67	First Stage Solid Propellant		8/28/2013 16:52	1	1	0	0	1	0	0
10724	ST.LV.A1.PW	Electrical Power Generation, Control and Distribution		8/28/2013 14:21	4	1	2	0	2	0	0
10725	ST.LV.A1.PW.PD	Electrical Power Distribution		8/28/2013 14:21	4	1	2	0	2	0	0
10789	ST.LV.A1.PW.PD.35	First Stage Electrical Power Cabling	Ignition power is provided from ground or from upstage source c	9/4/2013 14:10	4	1	2	0	2	0	0
10852	ST.LV.A1.TP	Thermal Control		8/28/2013 14:23	2	1	2	0	0	0	0
10853	ST.LV.A1.TP.PN	Passive Thermal Protection		8/28/2013 14:23	2	1	2	0	0	0	0
10854	ST.LV.A1.TP.PN.BL	Thermal Blanket TPS Components	(Only for Pad launch option)	8/28/2013 16:57	2	1	2	0	0	0	0
10855	ST.LV.A1.EC	Environmental Control		8/28/2013 14:34	2	1	2	0	0	0	0
10857	ST.LV.A1.EC.EP	Pressure Control		8/28/2013 14:36	2	1	2	0	0	0	0

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14. ABSTRACT

Life cycle technology impact comparisons for nanolauncher technology concepts were performed using an Affordability Comparison Tool (ACT) prototype. Examined are cost drivers and whether technology investments can dramatically affect the life cycle characteristics. Primary among the selected applications was the prospect of improving nanolauncher systems. As a result, findings and conclusions are documented for ways of creating more productive and affordable nanolauncher systems; e.g., an Express Lane-Flex Lane concept is forwarded, and the beneficial effect of incorporating advanced integrated avionics is explored. Also, a Functional Systems Breakdown Structure (F-SBS) was developed to derive consistent definitions of the flight and ground systems for both system performance and life cycle analysis. Further, a comprehensive catalog of ground segment functions was created.

15. SUBJECT TERMS
life cycle, technology impact comparison, nanolauncher, Express Lane, Flex Lane, launch vehicle, affordability, Skylon, system breakdown structure, SBS

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