ORGANIZATIONAL CONSIDERATIONS FOR IMPLEMENTING SYSTEMS ENGINEERING AND INTEGRATION IN THE ARES PROJECTS OFFICE

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ABSTRACT

Systems Engineering and Integration (SE&I) is a critical discipline for developing new space systems. In 2005, NASA performed an internal study of 24 NASA and Department of Defense (DoD) programs to evaluate methods of integrating SE&I practices and determine their effectiveness. The goal of the study was to determine the best SE&I implementation strategy for the Ares Projects. The study identified six SE&I organizational structures, encompassing an array of relationships and levels of responsibility between government agencies and other participating parties. The organizational structure used most often was using a prime contractor with government SE&I responsibility and government technical insight. However, data analyses did not establish a positive relationship between program success or development costs and specific SE&I organizational types. The study determined that large, long-duration, complex programs reach their technical goals, but rarely meet schedule or cost goals. Programs have failed or been terminated due to lack of technical insight, relaxing of SE&I processes, and unstable external factors. While any organizational structure can be made to work, success is more likely with fewer program complexities. This study was instrumental in helping Ares select an organizational structure following the same SE&I and oversight process used during the Apollo program.

FULL TEXT

Introduction

Systems Engineering and Integration (SE&I) is a critical discipline for developing new space systems. SE&I grew out of the need to ensure cost and technical performance in U.S. ballistic missile and space launch systems in the 1950s and 1960s:

> Scientists and engineers found that they needed some individuals to coordinate the information flowing among working groups. These 'systems engineers' created and maintained documents that reflected the current design, and they coordinated design changes with all those involved in the program.[i]

For organizations to learn, adapt, and sustain adaptations, they must have processes that are both flexible and durable.[ii] Therefore, the Ares Projects' management team wanted an organizational structure that met those needs as well as the overarching requirements of the U.S. Space Exploration Policy. These requirements include replacing the Space Shuttle's crew and cargo-carrying capabilities to the International Space Station (ISS) and building launch vehicles capable of transporting crew and cargo to the Moon and beyond.

In 2005, NASA performed an internal study of 24 NASA and Department of Defense (DoD) programs to evaluate the effectiveness of various methods of integrating SE&I practices. The goal of the study was to determine the best SE&I implementation strategy for the Ares Projects.

1.0 Study Overview and Requirements

The SE&I study overview included a description of Ares' basic SE&I requirements, study ground rules and assumptions, methodology, program/project selection rationale, a template used for data collection, and a description of program types included in the study.

To ensure proper SE&I implementation, the study mandated the following requirements:

- The government has ultimate responsibility for the Project's outcome.
- The Project must have a Systems Integrator (either government or contractor).
- There must be adequate competencies/ resources available to perform Project tasks.

The third point was of particular concern for the Ares team, as NASA would need to rebuild its internal competencies in SE&I and vehicle design.

1.1 Study Ground Rules and Assumptions

The study's ground rules and assumptions provided a common baseline for the options considered. These ground rules and assumptions included:

- References for actual cost trending came from the Resource Data Storage and Retrieval (REDSTAR) database, which served as the basis for the recent NASA cost growth study. DoD cost estimates were extracted from General Accounting Office (GAO) reports and other public news sources. The data to support the study were derived from public websites and personal interviews (lessons learned). To the extent possible, more than two personal interviews were conducted for each program/project. Interviewees represented various program/project disciplines.
- Programs/projects were considered "technically successful" if the primary mission objectives were met. Similarly, a program/project was considered a "failure" if the primary mission objectives were not met.
- Terminated programs/projects refer to programs/projects that were terminated during development.

1.2 Study Methodology

The study used the following methodology to analyze SE&I organizational structures and implementation, identify common trends across DoD and NASA programs/ projects, and identify independent factors influencing program/project outcomes:

- Identified SE&I organizational considerations.
- Defined metrics.
- Identified NASA/DoD programs/projects for the study.
- Completed a program/project template.
- Collected data/conducted interviews.
- Reviewed independent reports/GAO reports for lessons learned/recommendations.
- Identified factors that influenced SE&I implementation across programs/projects.
- Assessed data and identified "best practices" and lessons learned across programs/projects related to SE&I implementation.

2.0 *Columbia* and the Need for Improved Systems Engineering Practices

The SE&I study included a review of the recommendations from the Columbia Accident Investigation Board (CAIB) Report[iii] and the Diaz Commission, which was formed soon after CAIB. The Diaz Commission was chartered to analyze the implications of the CAIB findings for other NASA programs. SE&I-related CAIB findings and recommendations are summarized below:

- "F7.4-3: Over the last two decades, little to no progress has been made toward attaining integrated, independent, and detailed analyses of risk to the Space Shuttle system.
- F7.4-4: System safety engineering and management is separated from mainstream engineering, is not vigorous enough to have an impact on system design, and is hidden in the other safety disciplines at NASA HQ.
- F7.4-5: Risk information and data from hazard analyses are not communicated effectively to the risk assessment and mission assurance processes. The [CAIB] Board could not find adequate application of a process, database, or metric analysis tool that took an integrated, systemic view of the entire Space Shuttle system.
- F7.4-6: The Space Shuttle Systems Integration Office handles all Shuttle systems except the Orbiter. Therefore, it is not a true integration office.
- R7.5-1: Establish an independent Technical Engineering Authority that is responsible for technical requirements and all waivers to them, and will build a disciplined, systemic approach to identifying, analyzing, and controlling hazards throughout the life cycle of the Shuttle System. The independent technical authority does the following as a minimum:
  - Develop and maintain technical standards for all Space Shuttle Program projects and elements;
  - Be the sole waiver-granting authority for all technical standards;
  - Conduct trend and risk analysis at the subsystem, system, and enterprise levels;

– Own the failure mode, effects analysis, and hazard reporting systems;
– Conduct integrated hazard analysis;
– Decide what is and is not an anomalous event;
– Independently verify launch readiness; and
– Approve the provisions of the re-certification program called for in Recommendation.

- R9.1-1: The Technical Engineering Authority should be funded directly from NASA HQ, and should have no connection to or responsibility for schedule or program cost.
- R7.5-2: NASA HQ Office of Safety and Mission Assurance should have direct line authority over the entire Space Shuttle Program safety organization and should be independently resourced.
- R7.5-3: Reorganize the Space Shuttle Integration Office to make it capable of integrating all elements of the Space Shuttle Program, including the Orbiter.
- R9.1-1: Prepare a detailed plan for defining, establishing, transitioning, and implementing an independent Technical Engineering Authority, independent safety program, and a reorganized Space Shuttle Integration Office as described in R7.5-1, R7.5-2, and R7.5-3. In addition, NASA should submit annual reports to Congress, as apart of the budget review process, on its implementation activities."

Finally, the CAIB Report (p. 179) stated: "As a result [of the Space Flight Operations contract], experienced engineers changed jobs, NASA grew dependent on contractors for technical support, contract monitoring increased, and positions were subsequently staffed by less experienced engineers who were placed in management roles. Collectively, this eroded NASA's in-house engineering and technical capabilities."

The CAIB report and the Diaz Commission both addressed common themes, as depicted in Figure 1. The most important finding is that NASA needs to rebuild its SE&I leadership and technical capabilities.

This study was designed and executed with the results of the CAIB and the Diaz panels in mind. The goal was to give the agency information resulting in an organization capable of addressing the problems noted in these reports.

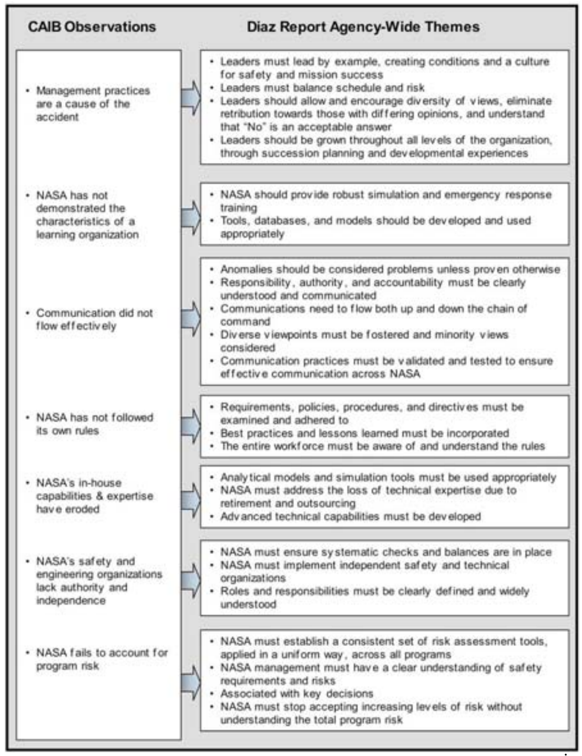

Figure 1. CAIB and Diaz Commission observations[iv] clearly mapped NASA's SE&I challenges.

3.0 Program/Project Types Included in the Study

The study examined the SE&I implementation capabilities of 24 NASA/DoD programs/projects. These programs/projects were selected to provide the greatest range of characteristics and to represent both past and current SE&I implementation efforts. The following factors were considered in determining which programs/projects to study:

- Small projects to large programs.
- Successful versus failed/terminated programs/projects.
- Completed and ongoing development.
- Data availability (based on study time constraints).

Table 1 provides a summary of the program/project types, the associated development times, and current program/project phases. Failed or terminated programs are highlighted in red.

Table 1. Selected Program/Project Type Summary**.**

Program Type	Duration (DDT&E) (Years)	Current Phase
Program 1	2.5	Operational
Program 2	3	Mission Failure
Program 3	3	Mission Failure
Program 4	3	Operational
Program 5	3	Mission completion
Program 6	5	Terminated
Program 7	5	Terminated
Program 8	6	Integration & Test
Program 9	6	Operational
Program 10	7	Operational
Program 11	7	Operational
Program 12	8	Mission Failure
Program 13	8	Development
Program 14	8	Development
Program 15	8	Operational
Program 16	9	Operational
Program 17	9	Operational
Program 18	9	Operational
Program 19	11	Mission Completion
Program 20	11	Development
Program 21	11	Operational
Program 22	12	Development
Program 23	23	Terminated
Program 24	24	Operational

In evaluating these programs/projects, the study identified six primary SE&I organizational structures:

1. Lead systems integrator (LSI) with SE&I responsibility and government technical insight.
2a. Integration contractor with government SE&I responsibility (government insight).
2b. Integration contractor with government SE&I responsibility (government oversight).
3a. Prime contractor with SE&I responsibility (government insight).
3b. Prime contractor with SE&I responsibility (government oversight).
3c. Prime contractor with SE&I responsibility (government/industry partnership).
4a. Prime contractor with government SE&I responsibility (government insight).
4b. Prime contractor with government SE&I responsibility (government oversight).
4d. Prime contractors with total system performance responsibility (TSPR).
5. Prime contractor with government SE&I responsibility and integration products through a Federally Funded Research and Development Center (FFRDC).
6. Government/FFRDC in-house development with SE&I responsibility and function.

Detailed descriptions of these program/project types are provided below. However, the following terms will first be defined for clarity and consistency.

- Oversight: Using government resources to monitor all aspects of contractor performance in product delivery and execution of approved processes.
- Insight: A customer's risk-based understanding, validation, and surveillance of a supplier's management systems and process performance metrics to assure product quality and contract compliance.
- Conventional Prime Contractor: Develops and builds what it can and subcontracts out what it cannot. A prime contractor provides an end item to the government.
- Lead Systems Integrator (LSI): Plans and performs Program Management (PM), Systems Engineering (SE), Systems Integration (SI), and acquisition.
- System-of-Systems (SoS): A set or arrangement of interdependent systems that are related or connected to provide a given capability. The loss of any part of the system will degrade the performance or capabilities of the whole. An example of an SoS could be interdependent information systems. While individual systems within the SoS may be developed to satisfy the peculiar needs of a given user group (such as a specific service or agency), the information they share is so important that the loss of a single system may deprive other systems of the data needed to achieve even minimal capabilities.
- Total System Performance Responsibility (TSPR): Under a TSPR contract, the contractor assumes responsibility for system life-cycle management. The anticipated benefits of a TSPR arrangement include decreased product delivery time, reduced costs and data, reduced program office manpower, fewer Engineering Change Proposals (ECP), reduced total ownership cost, and increased quality and readiness. (TSPR is also referred to as Full Services Contracting.) The government does not typically provide the traditional level of government oversight with this type of contract.

The six primary types of organizational relationships listed previously are detailed below and depicted in block diagram form in Figure 2.

1. LSI with SE&I responsibility.

- Little/no hardware/soft ware development responsibility for the LSI.
- LSI issues most/all subcontracts.
- Responsible for total systems performance.

2a. Integration contractor with government SE&I responsibility (may also be a prime contractor, with a separate integration task/contract).

- Integration contractor performs SE&I functions across multiple primes.
- Government-issued prime contracts.
- Government insight.

2b. Integration contractor with government SE&I responsibility (may also be a prime contractor, with a separate integration task/contract).

- Integration contractor performs SE&I functions across multiple primes.
- Government-issued prime contracts.
- Government oversight.

3a. Prime contractor with SE&I responsibility.

- Issues all subcontracts.
- Government insight.

3b. Prime contractor with SE&I responsibility.

- Issues all subcontracts.
- Government oversight.

3c. Prime contractor with SE&I responsibility (government/industry partnership).

- Issues all subcontracts.
- Government insight.

4a. Prime contractor with government SE&I responsibility.

- Both government and prime contractor issue contracts.
- Government insight.

4b. Prime contractor with government SE&I responsibility.

- Both government and prime contractor issue contracts.
- Government oversight.

4d. Prime contractor with TSPR.

- Both government and prime contractor issue contracts.
- Government insight.

5. Prime Contractor with government SE&I responsibility and SE&I products (through FFRDC/ Systems Engineering Technical Assistants (SETA)).

- Performs integration analysis, using contractors/SE Technical Assistants (SETA) or FFRDCs perform SE&I function.

6. Government (FFRDC) in-house development with SE&I responsibility and SE&I function.

- Government and FFRDC issue contracts.

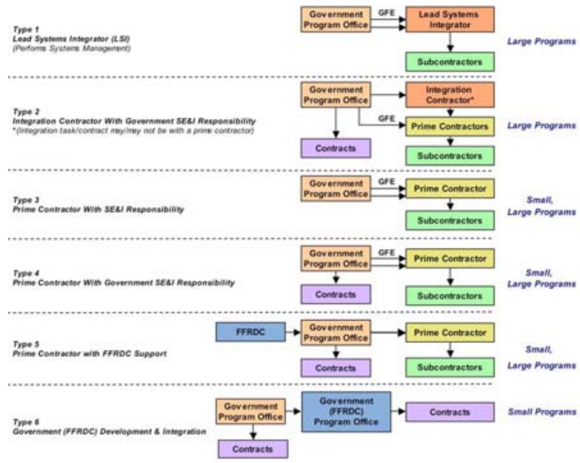

Figure 2. The block diagrams depict the operating relationships between government and its partners for the various program types.

3.1 Program Characteristics/SE&I Organizational Structure Relationships

The six SE&I organizational types each have key program characteristics associated with them. Program characteristic variables include: cost, development time, production rates, architecture type (modular, integrated), international partners, operational environment (geosynchronous, deep space, etc.), number of development locations (government only), number of critical technologies, and new infrastructure requirements.

- Type 1: Similar characteristics include net-centric, tightly integrated architectures, long development phases (greater than 8 years), large number of critical technologies, new infrastructure development, long operational phase, and development costs greater than $5 billion.
- Type 2: Similar characteristics include long development phases (greater than 5 years), modular architectures, multiple government development locations, and new infrastructure requirements.
- Types 3 and 4: Types 3 and 4 represented 14 of the 24 programs. Common Type 3 program/project characteristics included modular architectures, limited production, and new infrastructure requirements. There were varying characteristics across Type 4 SE&I organizational types.
- Type 5: Only one type program was included in this study.
- Type 6: Similar characteristics included short development schedules, with high

heritage (design/hardware) modular architectures.

3.2 Advantages and Disadvantages of Program/Project Types

The study identified key strengths and concerns for each of the program types, which are addressed below.

Type 1: LSI with SE&I Responsibility[1]

In these types of programs, little or no hardware/software development is performed. The LSI issues most or all of the contracts and is responsible for total systems performance.

This type of organization is typically implemented for large programs, with net-centric, integrated architectures, and multiple technology developments/insertions.

Key Strengths

- Competition during concept phase.
- Reduced government contract administration.
- Contracts administered by one source (LSI).
- Flexibility in acquiring core competencies to support long-term development.

Significant Areas to Address in Implementation Planning

- Project management (PM) and technical expertise for government personnel are needed to monitor programs.
- Program uncertainties derived from external factors can lead to significant change orders that require recurring system assessments, impacts to contracts, and Earned Value Management (EVM).
- Firewall/proprietary data issues associated with competitive acquisition.
- Addressing the multiple standards/processes/test philosophies existing across multiple government organizations/industry participants.
- Handling of government legacy hardware/facilities/contracts and international partner deliverables that are not typically included in LSI contract (key feature of LSI is management of all contracts for supporting integrated trades, interface definition, and analyses, commonality, interoperability, integrated risk management, and integrated testing).
- Clear definition of government/industry roles and responsibilities and decision-making process.
- International partner roles, responsibilities, contractual structure, and participation in interface definition and implementation.
- Alignment of government/industry organizational structures to support joint teaming.
- Data rights issues and proprietary data are issues for modeling and simulation and for capturing the design to ensure that government captures that knowledge.
- Impacts of staggered element development on the overall SE&I function.
- Organizational conflicts of interest.

Type 2: Integration Contractor with Government SE&I Responsibility

These programs/projects perform SE&I functions across multiple prime contractors, where the contract may be issued to one of the prime contractors, as a separate contract/task.

This type of organization is typically implemented for large programs with multiple prime contractors associated with multiple government locations.

Key Strengths

- Clear government responsibility for the design and development, and system performance.
- Single point of contact for the SE&I function.
- Flexibility in acquiring core competencies across program life cycle.
- The ability of the integration contractor to compete for other program work is dependent on program characteristics and is determined by program management.

Significant Areas to Address in Implementation Planning

- Contractual agreements between the integration contractor and other primes, international partners, or government-developed equipment/facilities are necessary

[*] Programs included in study are still in development stage/limited lessons learned for supporting implementation assessment

to support integrated trades, analyses, and tests.

- Contractual agreements between integration contractor and prime contractor, even if they are part of the same company.
- Program uncertainties derived from external factors can lead to significant change orders, requiring recurring system assessments, impacts to contracts, and EVM.
- Risk assessment for determining government technical involvement, independent analyses, and verification.
- Defining clear roles and responsibilities for the multiple government organizations/industry participants.
- Alignment of government/industry organizational structures to support joint government/industry teaming.
- Decision authority and program control board process across multiple primes for effective interface definition and management.
- International partner roles, responsibilities, contractual structure, and participation in interface definition and implementation.
- Addressing the multiple standards/processes/test philosophies have existing across multiple government organizations and industry.
- Data rights issues, proprietary data issues for modeling and simulation and for capturing design to ensure knowledge capture by the government.
- Impacts of staggered element development on overall the SE&I function.
- Organizational conflicts of interest.

Type 3: Prime Contractor with SE&I Responsibility (includes Government/Industry Partnerships)

In these types of programs/projects, the Prime Contractor issues all contracts. This organizational structure is typically implemented for large and small programs, with various types of architectures.

Key Strengths

- Reduced government administrative overhead.
- Reduced government technical support.
- Increased flexibility for the prime contractor.
- All contracts managed by one prime contractor.

Significant Areas to Address in Implementation Planning

- Government's visibility into program/project management control (programmatic and technical).
- Clearly defined roles and responsibilities for government and industry personnel (life cycle).
- Risk assessment for determining government technical involvement, independent analyses, and verification.
- Decision-making authority definition.
- Impacts of changes in anticipated customer base/market on partnership.
- Impacts of technical challenges during development phase on partnership.
- Other external factors impact on either prime contract/partnership.
- Data rights issues, proprietary data issues for modeling and simulation and for capturing design to ensure knowledge capture by the government.
- Impacts of staggered element development on overall SE&I function.
- Organizational conflicts of interest.

Type 4: Prime Contractor with Government SE&I Responsibility

In these types of programs/projects, both government and industry issue and manage contracts. The organizational structure is implemented for both large and small programs.

Key Strengths

- Clear government SE&I responsibility.
- Requirements allocation and balancing across program elements throughout development phase decreases the potential for conflict of interest.
- Minimizes potential for organizational conflicts of interest.

Significant Areas to Address in Implementation Planning

- International partner roles, responsibilities, and participation in interface definition and implementation.

- External factor impacts on SE&I resources, standards/processes, and integrated testing.
- Integration contracts between prime and government-managed contracts support timely and effective interface definition, analyses, issue resolution, integrated testing, standards, and processes.
- Multiple reporting paths to government program management's impact on requirements allocation, resources, etc.
- Data rights issues, proprietary data issues for modeling and simulation and for capturing design to ensure knowledge capture by the government.
- Impacts of staggered element development on overall SE&I function.

Type 5: Prime Contractor with Government SE&I Responsibility & SE&I Function

In this organization, government issues a prime contract for development and launch services. The organizational structure means that a government FFRDC provides analytical integration. This structure has been implemented for both large and small programs.

Key Strengths

- Clear government responsibility for interface product development and analytical integration across system.
- Provides continuous and consistent independent risk-based analyses.
- Timely interface issue identification and resolution.
- Resource flexibility with FFRDC program support.
- Minimizes potential for organizational conflicts of interest.

Significant Areas to Address in Implementation Planning

- PM and technical expertise for government personnel.
- Long-term FFRDC commitment.
- Data rights issues and proprietary data issues for modeling and simulation and for capturing design to ensure the government captures that knowledge.
- Impacts of staggered element development on overall SE&I function.

Type 6: Government In-House Development with SE&I Responsibility and Function

In this type of program/project, both the government and FFRDC issue contracts. The organizational structure is implemented for small programs, with focused, critical technology developments/insertions.

Implementation Strengths

- Clear government (FFRDC) responsibility for management and integration of system.
- Strengthening of FFRDC PM and technical core competencies.
- Flexibility in selection of core competencies across program life cycle.
- All contracts and SE&I managed by one entity, with minimal/no potential for conflicts of interest.

Other Areas to Address in Implementation Strategy

- Government PM and technical expertise government.
- Long-term FFRDC commitment.
- Multiple reporting paths to government program management impacts requirements allocation, resources, etc.

4.0 Other Factors Affecting Program/Project Success

Several key independent external and internal factors, relevant to SE&I implementation, were identified as part of this study, through individual program/project lessons learned, independent assessment reports and interviews.

4.1 External Factors

External factors included major policy/mission changes, funding instabilities/inadequate reserves, tight programmatic constraints (funding/schedule caps), multiple reporting management paths, and change in customer/contractor base.

4.2 Internal Factors

Internal factors were identified as lack of integration agreements between various contractors, lack of technical oversight, poor communications, multiple critical technologies, inadequate risk management, lack of rigorous processes and standards, lack of core competencies, lack of independent analyses, lack of comprehensive integrated tests, large number of complex interfaces, Modeling and Simulation (M&S)

issues, international partnership technical issues, and lack of effective and timely integrating solutions across multiple organizations.

4.3 Cross-Cutting Trends of Successful Programs/Projects

Characteristics of successful programs/projects with minimal or no-cost overruns were evaluated as part of the study. Common characteristics included:

- Funding stability/adequate reserves.
- Experienced program management.
- Limited critical technologies, with high heritage designs.
- Strong communications (implemented through "badgeless" teams).
- Application of rigorous standards/processes.
- Less than or equal to 7 year development effort.
- Successful programs had the least number of internal/external factors identified by the study.

A survey in *IEEE Engineering Management Review* examined the "capacity for engineering systems thinking (CEST)," and asked professionals in the field their opinions of what particular abilities and skills were necessary for effective SE&I. Among the CEST capabilities were:

- Understanding the whole system and seeing the big picture
- Understanding interconnections and "closed-loop" thinking – i.e., a "circular" view of issue causality rather than straight-line, "linear" thinking – the ability to offer several possible explanations for a problem, not only one
- Understanding systems synergy – i.e., the ability to identify new forms of integration or emergent properties of combined systems
- Understanding the system from multiple perspectives
- Thinking creatively
- Understanding systems without getting stuck on details; tolerance for ambiguity and uncertainty
- Understanding the implications of a proposed change
- Understanding a new system/concept immediately upon presentation
- Understanding analogies and parallelism between systems
- Understanding limits to growth.

NASA managers for the Apollo lunar program cited the agency's internal expertise as a critical success factor for landing a man on the Moon within a decade: "[Research and Development Operations] provides technical knowledge in depth to solve the technical problems, but at the same time carefully avoiding any interference with contract management."[v] Based on Wernher von Braun's experiences at Peenemünde and Redstone Arsenal, the early Apollo organization used an "arsenal" management style, which required a highly capable in-house knowledge base that sought contractor assistance only for production purposes. Von Braun emphasized a "dirty hands" approach to engineering among his technical team as the best preparation for evaluating contractor standards and proposals.[vi]

At a panel discussion honoring the 20th anniversary of the Apollo 11 landing, NASA managers Maxime Faget and Christopher Kraft echoed these sentiments on in-house technical competence. Faget stated, "I think we were ahead of the contractors. As a matter of fact, before we even put the [request for proposal] out, we pretty much knew what we wanted and stated it. The Apollo Command Module was designed more or less by our people."[vii] Chris Kraft seconded Faget's comments, saying, "I think that what we recognize, from Mercury to Gemini to Apollo, was that we needed a certain percentage of funds to do these kinds of things in Max's laboratory which gave our people straight, hands-on knowledge, first-hand knowledge, and it allowed us to build system that we built…to use in Apollo."[viii]

These are some of the abilities that the Ares Projects must teach and encourage if they are to institutionalize systems engineering as a core NASA competency in the future.

4.4 Cross-Cutting Trends of Failed/Terminated Programs/Projects

Program characteristics of successful programs/projects were also evaluated as part of the study. Common characteristics included the following:

- Funding instability.
- Government insight, or insight transitioned to oversight during development.
- Poorly executed systems engineering processes.

- Failed/terminated programs had a significant number of the external/internal factors present.

4.5 Benchmarking

Upon conclusion of this study, NASA performed a benchmarking study to investigate SE&I practices in companies and organizations outside of the aerospace industry. The benchmarking studies had two major goals: incorporate innovative practices from other industries and validate the results of this study. The initial selection criteria for study companies included:

- Long-term, high-risk/reward programs
- Need and ability to manage multiple technical and programmatic interfaces
- Need and ability to manage multiple supplies and to mitigate organizations conflicts of interest
- Ability to perform continuous technology infusion throughout the life cycle of the program

Approximately 50 organizations were initially selected and 5 organizations were chosen for benchmark visits. These organizations included consumer products, construction and engineering management, telecommunications, integrated energy producers and retailers, and a large military development program.

5.0 Conclusions

Over a two-month period, the study team derived a number of key conclusions that were decisive in determining which type of organization structure the Ares Projects would eventually use.
First, large, long-duration, technically complex programs/projects identified in the study that met high-level technical requirements have rarely met schedule and have far exceeded original cost estimates. There is evidence that all of these programs/projects have been significantly impacted by external factors, regardless of the SE&I organizational structure type.

Second, NASA's recent successes have been with smaller, short-duration development programs/projects, using heritage hardware/software, focused technology development, technical oversight, "badge-less" teaming, and stable external factors.

Third, program/project failure/termination common trends include technical insight, SE&I process relaxation, and unstable external factors.

Fourth, independent report findings cited review and oversight performance/ process, culture/communications, and budget/cost estimates, as the most common areas for improvement.

Fifth, There is no clear optimum SE&I organizational structure type (i.e., no one size fits all). Both implementation of the various SE&I organizational types, and independent factors appear to influence program outcome. Each SE&I organizational structure type has its own strengths and weaknesses, and any SE&I organizational structure can be made to work given time and effort. Addressing these implementation findings during program planning can improve a program's/ project's probability of success. Programs with the least number of factors present during development appeared to meet mission objectives, with minimal cost and schedule overrun. Failed/terminated programs had a significant number of these factors present. Current programs with a significant number of these factors have already experienced cost and schedule overruns.

Sixth, evolving system complexities and integrated architectures add to the complexity of implementing successful SE&I across programs/projects, including M&S, where tool ownership, implementation, and proprietary data issues have been identified.

Seventh, the most common successful SE&I organizational structure type in this study was the structure Type 4b, where government maintained integration responsibility, with the prime contractor providing SE&I products and the government providing technical oversight. This organizational type has been implemented by both small and large programs, with varying program characteristics.

Eighth, there was not sufficient data to establish a relationship between program development costs and a specific SE&I organizational type selection. Type 1 programs were not implemented for the smaller development budgets. Similarly, Type 6 programs were not implemented for the larger development budgets. Type 2, 3, and 4 programs were observed for both small- and large-budget categories.

The results of the benchmarking studies also validated these conclusions. Each organization operated under different approaches to systems engineering (while most did not refer to it in that manner), and each had varying results of success on large programs. One common thread among successful companies was the organization held ultimate responsibility for the success or failure of the product and did not rely on a supplier for total performance responsibility. In addition, the successful organizations had a rigorous method of controlling requirement changes and requirements creep, which add to the cost, schedule, and complexity of a project. Of course NASA need not rely solely upon data from outside organizations—our own history during the Apollo program demonstrates the value of in-house knowledge to executing successful operations.

Finally, there were some relationships between the program characteristics within each of the SE&I organizational structure types. For example, the Type 2 SE&I organization has been implemented for two major, long-duration, net-centric architectures, with multiple critical technologies. There were varying program characteristics within each SE&I organizational type for most of the other programs.

In the end, the Ares Projects management team elected to work within an organization where government maintained integration responsibility, with the prime contractor providing SE&I products and the government providing technical oversight. This structure was deemed the most beneficial for executing the Projects because it provides a minimum of organizational conflict while maximizing NASA's ability to improve and increase the scope of its SE&I activities.

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