The NASA Exploration Design Team; Blueprint for a New Design Paradigm

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NASA has chosen JPL to deliver a NASA-wide rapid-response real-time collaborative design team to perform rapid execution of program, system, mission, and technology trade studies. This team will draw on the expertise of all NASA centers and external partners necessary. The NASA Exploration Design Team (NEDT) will be led by NASA Headquarters, with field centers and partners added according to the needs of each study. Through real-time distributed collaboration we will effectively bring all NASA field centers directly inside Headquarters.

JPL's Team X pioneered the technique of real time collaborative design 8 years ago. Since its inception, Team X has performed over 600 mission studies and has reduced per-study cost by a factor of 5 and per-study duration by a factor of 10 compared to conventional design processes. The Team X concept has spread to other NASA centers, industry, academia, and international partners.

In this paper, we discuss the extension of the JPL Team X process to the NASA-wide collaborative design team. We discuss the architecture for such a process and elaborate on the implementation challenges of this process. We further discuss our current ideas on how to address these challenges.

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INTRODUCTION

In order to meet the Nation's goal of a new direction in human and robotic space exploration, NASA's Exploration Systems Mission Directorate (ESMD) plans to rapidly develop concepts, architectures, and requirements for the next generation of space exploration systems. This requires a rapid architectural design capability, quick access to the vast expertise distributed throughout NASA centers and external partners, and impartial analysis of options. To accomplish these goals, ESMD will lead a design team combining the expertise from each of the participating organizations.

This capability will be realized by connecting the NASA centers and external partners into a single unified team that will perform real-time on-demand architectural design and trade studies directly for ESMD. This is the NASA Exploration Design Team (NEDT).

NEDT will consist of teams at NASA centers and partners, collaborating in real-time and will be supported by integrated communication and engineering tools (see Figure 1). This concurrent engineering paradigm is expected to provide results in much less time and cost than the traditional serial design team process. The goal is for NEDT to provide a study turn-around time of approximately 2 weeks.

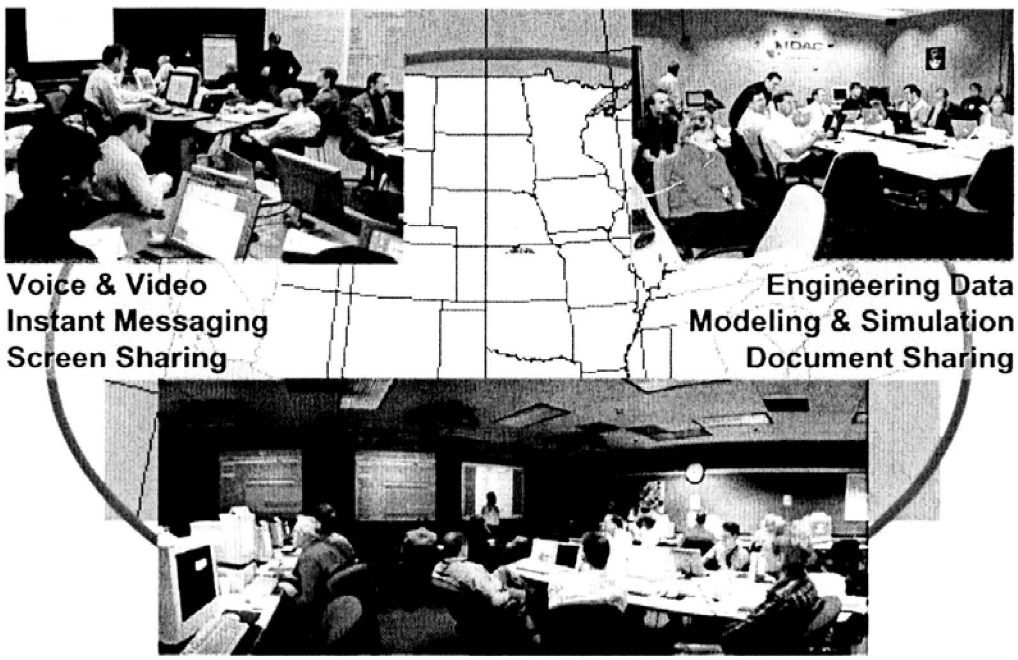

Figure 1 - Distributed Concurrent Engineering

To provide this capability the following thrusts are planned:

1. Connect NASA centers and partners via collaboration infrastructure, including:
   - Secure network connectivity through firewalls.
   - Integrate and upgrade existing collaboration tools (i.e. voice, video, and data sharing).
2. Train personnel in concurrent engineering techniques.
3. Integrate engineering tools, including:
   - Adoption of existing engineering design tools.
   - Connections to trade-space and simulation-based acquisition models.
   - Inter-center engineering parameter exchange.
4. Execute studies and deliver needed study results to ESMD with the shortest turn around time practicable in the new environment (< 2weeks).

This capability will draw upon the Jet Propulsion Laboratory's (JPL) Advanced Projects Design Team expertise. This team, also known as Team X, uses dedicated facilities, processes and design tools, in concert with a JPL-pioneered concurrent engineering approach to produce fast feasibility studies and proposals. Team X study statistics (shown in Table 1) have resulted in adoption of this concept by other NASA centers, industry, academia, and international partners.

Table 1. Concurrent Engineering Results Demonstrated by Team X

Studies Performed	630
Study Time Reduction	10x
Study Cost Reduction	5x

Neither Team X nor any other single design team can currently adequately serve ESMD due to the nature of their specializations (e.g. robotic missions, manned missions). NEDT will combine the expertise of all NASA centers and external partners in this regard. NEDT will be led by NASA Headquarters, with field centers and partners enlisted according to the needs of each study. Through real-time distributed collaboration NEDT will effectively bring the field centers directly inside NASA Headquarters. For the first time, NASA HQ will be able to initiate and conduct mission studies directly.

The development team will consist of leaders of Team X, Team Prometheus (Nuclear Systems Initiative distributed study team), and collaborative design facilities and teams across NASA. It is intended to gather all available experience within NASA to synthesize a world-class facility as well as organizational structure to provide distributed concurrent space system engineering.

NEDT Project development will be incremental, and will be executed over a period of three years.

NASA Exploration Systems Mission Directorate Needs

The Exploration Systems Mission Directorate (ESMD) will rapidly develop concepts, architectures, and requirements for the next generation of space exploration systems. In order to make informed decision in these areas ESMD faces daunting fundamental questions: how much will a certain architecture cost, what are the impacts of a certain technology, in what sequence should missions occur to optimally leverage technology developments, etc. Answering these questions requires the consistent, agile, and cost-effective execution of large numbers of conceptual space system design and trade studies, drawing on expertise across NASA and industry. ESMD needs in this area are listed in Table 2.

Table 2 - ESMD Needs Defined

Need	Definition
Agility	Rapid turnaround, rapid change of direction, ability to address disparate regimes, e.g., human & robotic.
Completeness & consistency	Standard roducts that are consistent between studies and organizations.
Cost effectiveness	Predictable cost per study, reduction in costs from current paradigm
Access to expertise	Access to world-class experts for reliable results.
Trade spaces	Must be able to assess a wide range of options to insure selection of optimal architectures.
Collaboration	Quickly include input from all pertinent organizations, inside and outside of NASA.
Access to Capability	HQ, and any NASA center, can exercise NASA-wide design capabilities.

Architecture for NEDT

The NASA Exploration Design Team (NEDT) will provide the necessary framework to meet these needs. NEDT is expected to be a rapid-response real-time concurrent engineering team that will perform mission and system design, and technology trade studies.

The NEDT will be developed in 2 phases. Phase 1 concentrates on basic capabilities in infrastructure, training and pilot studies with a limited set of partner institutions participating. A pilot study will be performed that will demonstrate the initial operational capability to support the ESMD mission. Phase 2 will expand the capability by incorporating additional NASA centers and industry partners into the team and expand the tools available for the design. Completion of these efforts will result in a full operational capability to address relevant ESMD design or assessment activities. The following are key features of the NEDT architecture for Phases 1 and 2.

Concurrent engineering paradigm-

NEDT will utilize the concurrent engineering paradigm to create an environment for the performance of studies in much less time and expense than conventional design. The conventional design process is shown in Figure 2. This process is generally characterized by cycles of issue resolution as shown in Figure 3, which can take days, weeks, or months. By comparison, with concurrent engineering (shown in Figure 4) all participants can work together in real-time, with physical or virtual collocation. Issues are rendered amenable to rapid identification and resolution with synchronous technical communication.

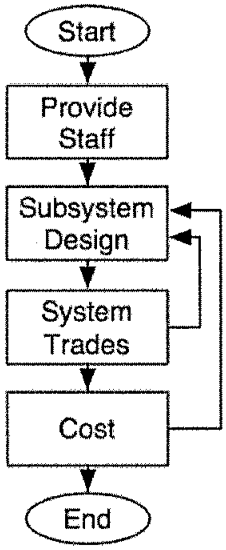

Figure 2.
Traditional Serial
Design Process

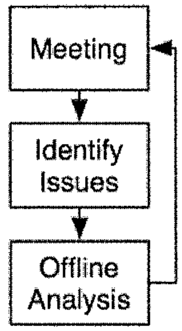

Figure 3.
Meeting & Issue
Process

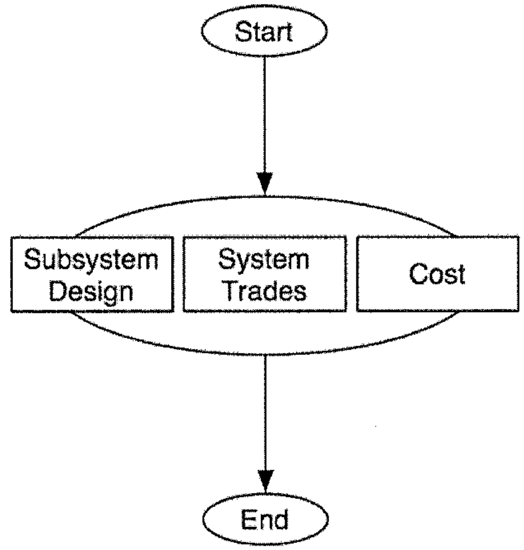

Figure 4.
Concurrent Engineering Process

Meeting cycles are eliminated. The entire design team can quickly change direction to instantly react to new information.

Multi-center real-time distributed collaboration has been demonstrated in limited form by Team Prometheus and other Team X studies involving industrial and international partners. Due to its JPL robotic mission focus, the Team X framework in its current form cannot be adapted directly to meet the needs of ESMD. Instead, JPL will expand the concept to a NASA-wide team capitalizing on the skills and assets available across NASA and its partners. The Aerospace Corporation will be an integral element of the team as a proxy for industrial partners. The issues in connecting and integrating Aerospace Corp. with the team will predict the challenges that will be faced in eventually integrating industrial partners.

Training and Team Building-
JPL will train study session participants in collaborative engineering methodologies. Training in concurrent engineering techniques will be provided "offline" via instruction from experienced personnel and "online" via participation in training and pilot studies. While it is likely that the existing concurrent engineering paradigm will initially be adopted, process developers will actively solicit feedback and discussions among team participants concerning the optimal team composition, process, and environment. By using training studies as team building exercises, it is intended that the core of the rapid design process can be retained while encouraging the team to evolve its own optimized process for operating in a distributed environment. By addressing actual ESMD problems in these studies the team will provide early results, address pressing needs, and demonstrate its value.

Process-
JPL will define the Team operating process and standard products, codify these in the Operations Concept, and refine these continuously through studies and customer feedback. The baseline operating process is as follows:

- HQ/ESMD identifies study need and provides study request to NEDT.
- ESMD and NEDT leaders formulate study requirements in pre-session videoconference(s).
- ESMD designates lead and participating NASA centers and partners.
- NEDT performs design study over 1 week. Study is facilitated by the lead center for the particular study. Lead center rolls up key engineering data from supporting centers.
- NEDT compiles and provides study report to ESMD over 1 week. Primary study results are system cost, performance, and risk.

Baseline study products will be:

- Mission objectives
- Key drivers & challenges
- Key components to be used
- Estimated cost, performance, risk, mass, power
- Estimated schedule & programmatics
- Operations overview
- Trajectory
- Design assumptions & trades conducted
- Launch vehicle
- Ground systems and networks
- Descriptions of structure, communication, propulsion, life support, power, & thermal systems

Infrastructure-

Currently existing infrastructure does not adequately support concurrent engineering. The largest shortcomings are data communications difficulties through firewalls and voice communications. JPL will establish through-firewall data communications paths between study participants and use these paths to connect existing engineering tools and collaboration infrastructure. For voice and video communications existing videoconferencing capabilities will be utilized and the engineering voice communications system that has been developed by Project Prometheus will be upgraded.

During Phase1, the NEDT will use existing infrastructure, with minimal modifications, to connect the initial centers; the emphasis will be on speed of deployment and obtaining minimum essential connectivity at the expense of permanence and robustness. Figures 5, through 8 show existing design centers at JPL, MSFC, GRC, and GSFC.

Figure 5. JPL Project Design Center

Figure 6. MSFC Collaborative Engineering Center

Figure 7. GRC Integrated Design & Analysis Center

Figure 8. GSFC Integrated Mission Design Center

In Phase 2, a more robust infrastructure based on requirements developed during the first phase will be implemented. Phase 2 will involve more complete engineering data exchange, voice and tool connectivity, video (depending on location), and connections to simulations.

COTS infrastructure solutions will be preferred, however, selected technology will be developed where COTS options are not adequate. Standards for collaboration infrastructure will be adopted (e.g., firewall/security standards, data protocols, engineering data formats) from COTS sources or elsewhere in NASA (e.g., ESMD CIO led collaboration infrastructure initiatives and Advanced Engineering Environment). JPL will work with external partners to establish their compatibility with these standards.

The NEDT Project will utilize existing infrastructure to the maximum extent possible and leverage developments in these areas elsewhere in NASA (e.g. ESMD CIO led collaboration infrastructure initiatives, Advanced Engineering Environment). Selected upgrades will be performed where existing capability is inadequate or does not exist.

Engineering Tools-
The project will begin with the engineering tools currently in use at the centers and Aerospace Corporation. These tools provide engineering analysis capabilities and vary widely in complexity and capability, ranging from simple spreadsheets to complex simuylations. NEDT will integrate externally supplied engineering, analysis, and modeling/simulation tools, including simulation-based acquisition models, as needed to address the analyses as required by ESMD studies.

Based on lessons learned in Phase 1, the project will actively solicit and integrate advanced engineering tools that are being developed under other ESMD technology efforts and will provide user feedback to the developers of such tools. In Phase 2, the project will connect NEDT with externally developed models (model-based design, simulation-based acquisition models, trade-space tools, etc.) so that the Team can provide driving design parameters to the models and evaluate the results.

Organizational Participation-
Phase 1 will include NASA Headquarters, Johnson Space Center (JSC), JPL, and Aerospace Corporation in design studies. Additional centers will be involved in requirements development, consulting, and tool preparation. The second phase will add Goddard Space Flight Center (GSFC), Ames Research Center (ARC), Glenn Research Center

(GRC), Marshall Space Flight Center (MSFC), Langley Research Center (LRC) and potential external partners in design studies. HQ will determine the specific role of each organization on a study-by-study basis, and in particular will decide which centers will lead and facilitate each study. JPL is not proposing to lead all studies but will rather develop the capability for any center to lead studies. Aerospace Corporation participation will serve as a pathfinder for collaboration with industrial partners, will provide technical expertise as appropriate, and may eventually serve as an independent technical assessor. The NASA Integrated Services Network (based at MSFC) will be utilized for infrastructure provisioning.

Infusion-
The project will perform design studies on an ongoing basis throughout the 3 years of this task. The studies will be directly applicable to ESMD; their content will be decided by ESMD. The project will solicit and incorporate feed-back from ESMD on tailoring the process and products to ESMD needs. Studies are planned to be co-funded by the customer.

Implementation Challenges

Many implementation challenges are anticipated during the development of the NEDT. In addition to the technical challenges involved with setting up the infrastructure and team processes, significant organizational challenges are also anticipated.

Some of the infrastructure and tools challenges anticipated:

- Incompatible collaboration tools across the agency
- NASA communication infrastructure may not be capable of handling peak loads
- Hardware and software may be incompatible or incomplete
- Headquarters currently has no room available for a design center – may need to be installed at JPL's Washington Office
- Infrastructure expertise may not be available at all centers
- Multi-user facilities may not be available when needed

Organizational challenges facing the NEDT development team include:

- Center priorities may interfere with implementation
- Domain specialists may not be available for studies
- Availability of key personnel
- Inter-center cooperation (what I'm getting at is the fact that in the environmement of competed missions it may be difficult)

One final challenge is that of customer involvement and training. The NEDT capabilities will evolve to meet the customer's needs only if there is active engagement.

Ideas on how to address these challenges

The NEDT development team has spent considerable effort to address the anticipated challenges.

Some of these challenges will be mitigated by the fact that the capability development will be done using an incre-mental, evolutionary approach. The initial capability will be based on Team X concurrent design experience. The plan involves integration of one NASA center at a time, so that lessons can be learned before large investments of resources are made. In addition, all centers will participate in the initial requirements analysis so that there are few surprises late in the implementation. The use of existing infrastructure wherever possible as well as COTS tools will help the team contain costs and will allow them to focus attention on other development priorities.

Training and team building are central to our approach. In addition, our test and validation approach involves a se-ries of tests executing a series of incrementally more challenging tests, verifying the functionality and processes that are developed. The test program culminates in the Pilot study, which is the proof of concept activities which demonstrates the Phase 1 capability. Phase 2 test activities will be similar and will depend on the requirements generated during Phase 1.

To meet the anticipated organizational challenges, the NEDT Project will secure commitments from supporting Centers and participating non-NASA organizations to act as responsible Partners and/or Suppliers, meeting agreed-to objectives with products produced on time and delivered on budget. These supporting Centers and/or other organizations will establish their own management structure to ensure that they honor this commitment to the Project. The Project will audit the plans and progress of the supporting Centers and/or other organizations in order to integrate their contributions into the overall objectives of the Project. All Partners and Suppliers will participate fully in day-to-day programmatic input to all integration activities as deemed appropriate by the Project management.

CONCLUSIONS

Although facing significant implementation challenges, the architectural approach and organization structure for the NEDT will effectively bring the field centers directly inside NASA Headquarters. For the first time, NASA Headquarters will be able to initiate and conduct mission studies directly. The real-time distributed collaboration approach has been shown to be both cost effective and timely. Because of this, NASA Headquarters will be able to explore the mission trade-space in much more detail than could have been done with a conventional design methodology.

Because it will draw on NASA-wide expertise and resources, the NEDT will have be able to address all ESMD missions, both human and robotic, and all Strategic Technical Challenges and technologies applicable to such missions. The team will be able to support NASA Headquarters in addressing both mission-specific and program-level issues. Studies will be designed to generate mission and system requirements and architectures, including designs, costs, and risk estimates. Study results will be used by Headquarters in designing and assessing specific missions, and in developing strategic program technology roadmaps and investment strategies.

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BIOGRAPHY

Needs to be inserted – I think just Bob's is needed

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Not sure if there are any
(maybe he could acknowledge me since I was ghost-writer)