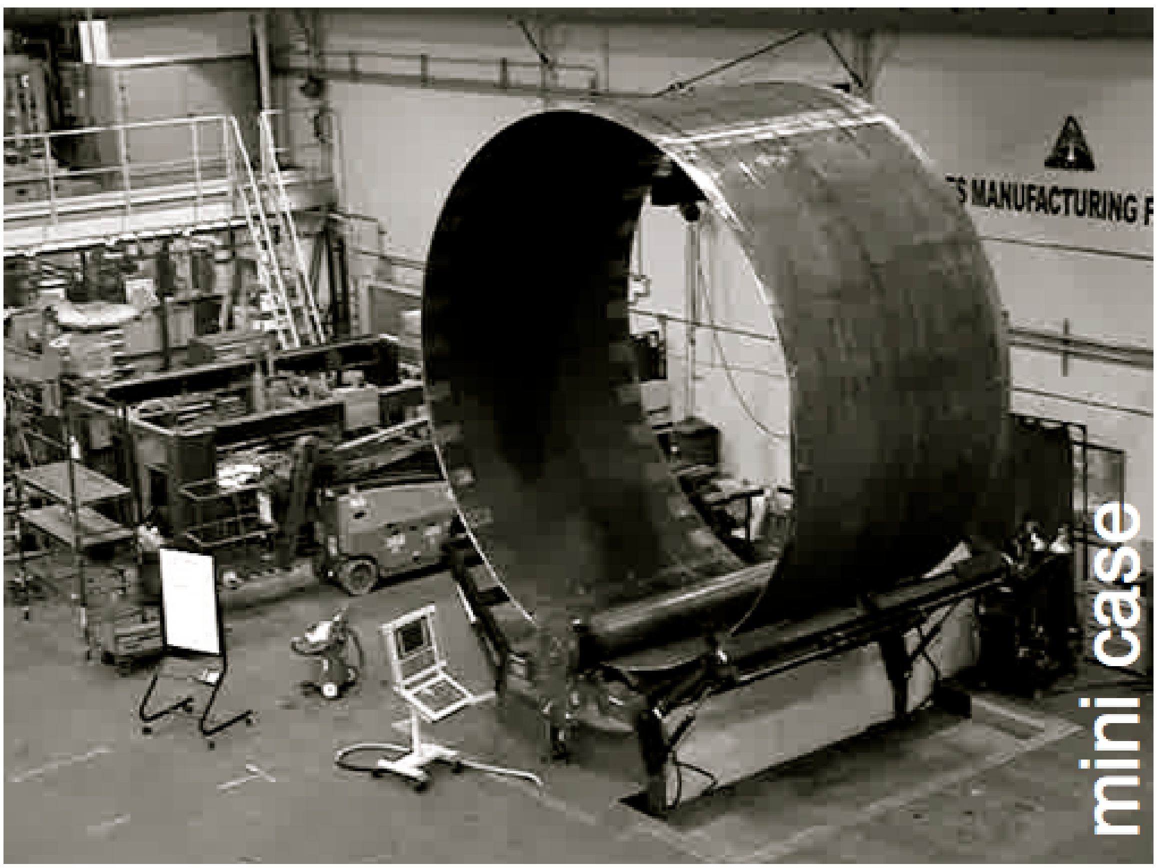
National Aeronautics and Space Administration

Academy of Program/Project & Engineering Leadership

Building the Team:

The Ares I-X Upper Stage Simulator



BUILDING THE TEAM: THE ARES I-X UPPER STAGE SIMULATOR

The opportunity to build a new launch vehicle that can loft humans into space does not come along often. The Ares family of launch vehicles, conceived in response to the Vision for Space Exploration, presented the first chance for NASA engineers to get hands-on experience designing and building human spaceflight hardware since the development of the Space Shuttle thirty years ago.

In 2005, NASA Headquarters solicited proposals from Integrated Product Teams for different segments of the Ares I-X test flight vehicle. The Ares I-X test flight objectives focused on first-stage flight dynamics, controllability, and separation of the first and upper stages. The launch vehicle would consist of a functional booster stage and an upper stage mass simulator, which would have the same mass as an actual upper stage but none of its functionality.

A team at Glenn Research Center prepared to bid for the job of building the Ares I-X Upper Stage Simulator (USS). The first challenge in bringing the Upper Stage Simulator to Glenn was assembling a core team with the right skills to develop a winning proposal. "Early on as we formulated, even before we had gotten authority to proceed but were doing concept studies, and cost and schedule estimations, I needed a good systems engineer to look across this conceptual simulator that we were coming up with and help us identify if we were missing any functions," said Vince Bilardo, who headed the proposal team and would eventually become the Project Manager. "We needed a good systems engineer to help us do a draft functional allocation."

As the proposal development period for the Upper Stage work progressed, Bilardo drafted Bill Foster to serve as his Lead Systems Engineer. Foster began attending systems engineering technical interchange meetings while Bilardo ran concept teams that drew up a series of designs ranging from high-fidelity and expensive to low-fidelity and inexpensive. "(Vince) had different teams laying out concepts, and that's where the first ‘tuna can’—the design we actually ended up with—came up. He ran those concept teams over a three-day period, and that kind of kicked everything off," Foster said.

The Glenn team continued to define its concepts and cost estimates as the Constellation program developed the requirements for the test vehicle. "The requirements were pointing us toward a higher fidelity simulator instead of a lower fidelity. So some of our concepts started to fall to the wayside while the higher fidelity one was really the only one that was going to pay off: the expensive one," said Bill Foster. "When we rolled that all up and Constellation was figuring out their budget, they said, ‘We're not doing high fidelity because it's way too expensive.’"

A few weeks later, Glenn came back with a significantly trimmed-down version of its low-fidelity proposal. "This low-fidelity launch did a few things. One, it gave us good flight data about ‘Can we launch this long, skinny rocket?’ Another thing was it was fairly inexpensive. Third, it was going to be an early launch (2009) to get this early data, whereas the high-fidelity version pushed out into 2011," said Foster. "That's what got us turned on (approved). At that point we started ramping up people."

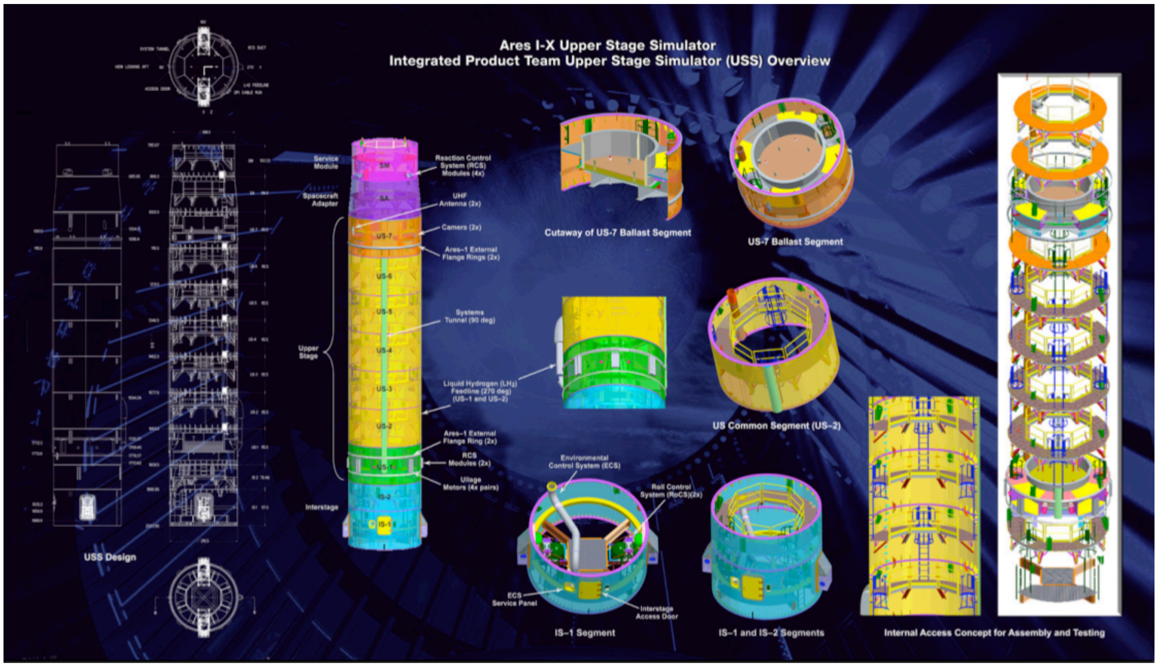


Figure 1. Overview of Ares I-X Upper Stage Simulator.

A Field Center in Transition

The significance of this assignment for Glenn could not be overstated. Most of the center's recent space flight project work consisted of developing small ("glove box") microgravity experiment payloads for the Space Shuttle and the International Space Station.

Just months before Bilardo's team received approval to build the Upper Stage Simulator, NASA Headquarters conducted a readiness review to determine Glenn's ability to manage significant space flight projects. Shortly thereafter, NASA Administrator Dr. Michael Griffin announced a policy of maintaining "ten healthy centers": each field center would "contribute to NASA's primary mission of space exploration and discovery."[1] Glenn would have to earn its assignments and its work would be closely supervised, but it would have a chance to revitalize itself.

[1] http://www.nasa.gov/home/hqnews/2006/feb/HQ_06056_Budget_Statement.html

An In-House Development

In May 2006, the Glenn team received provisional authority to proceed with the Upper Stage Simulator as an in-house project, meaning that it would design, develop, and build the hardware in its own facilities using its own technical workforce, rather than contracting the job out to private industry. (After a probationary period, the project got full authority to proceed in August.)

The selected design required manufacturing eleven segments of half-inch thick steel that stretched 18 feet in diameter and nine and a half feet tall. The job would incorporate all the basic hardware development functions: cutting, rolling, welding, inspecting, sandblasting, painting, drilling and tapping for instrumentation.

Since the project team was beginning with no in-house expertise in large-scale fabrication or manufacturing, it required an entirely new set of procedures that documented each step of the building and assembly process in exacting detail. Bilardo called on Dan Kocka, a recently minted engineer who had spent most of his career as a technician, to serve as the Production Planning Lead. Kocka had never assumed these duties before. "I said to Vince, are you sure I'm the right guy for this?" Kocka said. Bilardo was confident that Kocka's unique background would be an asset that would outweigh his relative lack of experience with the specifics of the job. Once the project got underway, Kocka's doubts dissipated; he found that his ability to think like an engineer and a technician served him well. "I really was in a good position to have both of these things going on at the same time in my mind," he said.

Back to School: Glenn Technical Education Development Program

Immediately prior to joining the Upper Stage Simulator team, Dan Kocka participated in the Glenn Technical Education Development (GTED) program. GTED provided selected applicants with an opportunity to enhance or acquire technical, scientific, and engineering knowledge through undergraduate academic training: it offered full-time support for planned academic study (not to exceed two years) at a local college or university in areas essential to Glenn's mission. Participants also received developmental assignments during academic breaks that gave them the opportunity to apply new knowledge and skills.

An additional challenge that fell heavily on Kocka concerned demonstrating compliance with AS 9100, an aerospace manufacturing quality standard. Glenn's management team was making a center-wide effort to achieve AS 9100 certification.[2] For the Upper Stage

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[2] AS 9100 is an international aerospace standard in the same family of standards as ISO 9001. See NASA Policy Directive NPD 8730.5 for more information: <http://nodis.hq.nasa.gov/displayDir.cfm?Internal_ID=N_PD_8730_0005_&page_name=main&search_term=%22AS%209100%22>

Simulator, this meant putting in place rigorously documented procedures that met with the approval of both the Safety and Mission Assurance organization and the technicians doing the work. The AS 9100 standard added another level of rigor to the process of designing and building space flight hardware.

Preparing for a fabrication job of this size and scope demanded a wholesale renovation of a facility: new cranes, new assembly platforms, and a new sheet metal roller. This meant retrofitting an older manufacturing shop floor that was large enough to accommodate the hardware. The facility modification had to be done quickly--in about three or four months -- so the project could begin work as scheduled on its first "pathfinder" segments.

"From a project management perspective, I needed somebody who could handle all that facilities work, and go work with the facilities organizations and the facilities directorate at Glenn and start planning, designing, and implementing the overhauls that we needed to accomplish in a very short period of time," said Vince Bilardo. He found Jack Lekan, an experienced project manager who was finishing up another job at the time. "Jack was a long-time Glenn guy who had excellent contacts across the center and a skill set that was very much oriented to team building and cooperation and working well with the various performing organizations. (He was) perfect for the job."

Ramping Up

Management of the Upper Stage Simulator project required constant interaction with the other three NASA field centers responsible for Ares I-X: Langley Research Center (systems engineering & integration office), Marshall Space Flight Center (first stage, avionics, and roll control system IPTs), and Kennedy Space Center (integration and test functions as well as the launch itself). Bilardo spent a significant amount of time traveling or otherwise coordinating with his counterparts at these centers. He needed a deputy project manager who could handle the "down-and-in" details of running the project on a daily basis.

He turned to Foster, his Lead Systems Engineer, who had project management experience from his years on microgravity science projects where he'd served as both the project manager and systems engineer. With Foster moving over to project management, the team needed a new Lead Systems Engineer. They brought in Tom Doehne, who was just finishing up a trade study for the Upper Stage Thrust Vector Control (TVC) System of the Ares I vehicle.

Doehne’s primary focus was on managing the design integration of the simulator hardware, documenting the design in the Design Definition Memorandum (DDM), and developing the project requirements. The design evolved and the requirements database kept expanding as the larger Ares I-X management team kept adding more requirements for the Upper Stage Simulator. He realized he needed more systems engineers to support the project. “Initially, I was the only systems engineer as we were developing this task, and we had a lot of work up front that we were trying to do in the early July-November (2006) timeframe,” he said.

Developing Systems Engineers: Space Mission Excellence Program

Tom Doehne had recently transitioned to systems engineering with almost 20 years of experience in-mechanical engineering as well as some experience in project management in ground and space hardware development. When he joined the Ares I-X team in June 2006, he was nearing completion of the Space Mission Excellence Program (SMEP), an accelerated and intensive one-year professional development program designed to address the need for systems engineering and integration capability at Glenn. The SMEP retains disciplined engineers using the Academy of Program/Project and Engineering Leadership (APPEL) core curriculum, supplemented with elective systems engineering courses and on-the-job-training. Additionally, technical mentorship, knowledge sharing and human systems effectiveness enriches the experience. “The transition from mechanical engineering to systems engineering was a natural transition for me considering the breadth of hardware that I was already developing,” Doehne said.

As the systems engineering workload increased leading up to a Systems Requirement Review (SRR), Doehne had trouble finding qualified systems engineers. The new Orion and Ares I projects at Glenn had been ramping up over the past year. Eventually he was able to transition two civil servants who were in the Space Mission Excellence Program (SMEP), as well as some experienced contractor support. “We took qualified engineers from other areas of the center who were in training as systems engineers. They received real project experience, and we were able to complete the large volume of work that was in front of us,” Doehne said.

In addition to knowledge and experience, Doehne valued team members who could remain engaged and be flexible on a project with an aggressive schedule and a rapidly changing context. “Team dynamics is also a very important key to building a successful project team and shouldn’t be mistaken for something that isn’t needed,” he said. “In today’s projects with limited budgets and aggressive schedules, we need to work as a cohesive team unit and have the ability to adapt to a dynamic work environment to achieve our common goal.”

“Welding Is Not Easy”

The scale of the Upper Stage Simulator demanded a manufacturing capability that didn't exist at Glenn. The recent focus of the center's manufacturing efforts had been on microgravity payloads that called for the highly intricate machining of sophisticated instruments, not on the rough fabrication skills needed to roll, weld, and attach large segments of a launch vehicle. This fundamental reorientation toward heavy manufacturing posed challenges both in terms of the workforce and the organization.

Glenn had several highly skilled machinists among its civil service workforce, but it had few fabricators and a critical shortage of welders. Since the center no longer had enough work to fully utilize the majority of its machinists, the project management team, in consultation with Glenn's upper management, set out to retrain a cadre of about twenty machinists as welders.

The retraining effort was well-intentioned, but it did not work as planned. "It turns out welding is not easy," said Bill Foster, who had advocated for hiring outside welders. Even with training, it took years of practice as a welder to achieve the level of proficiency that this job demanded. Flight quality welds must pass a litany of tests, including radiographic and ultrasonic inspections by certified weld inspectors. "Unless you are welding day in and day out for a living, it's really difficult to maintain the level of skills required to execute flawless welds that are going to fly on a flight test for NASA," said Vince Bilardo.

The next step was to hire welders on contract. The project reached out to some local non-union shops, which began sending over welders for qualifying tests. Again, the necessary skill level proved to be a formidable barrier. "They were probably washing out at a 60% rate," said Bill Foster. The project only retained the services of one of these shops, and they still needed more welders. A call went out for union welders. "Even then, with top-notch welders, we were getting about a 25% washout rate," said Foster.

The drawn-out hiring process cost the project time that it hadn't built into its schedule. Having found enough qualified welders, the project now had to align the number of welders on the shop floor with the work flow. "We needed a lot of welders at the beginning, but then we cut back because we were not able to keep them busy," said Foster. Then the pendulum swung too far in the other direction. "We cut back too far because things were going well and we hadn't gotten into the complicated segments. When we got into the complicated ones and the welding went back up, all of a sudden we needed welders again."

The juxtaposition of union and non-union welders in the manufacturing facility brought other issues to the shop floor. Some of the union welders did not want to work alongside their non-union counterparts, and in one instance there was a walk-off by the union welders. "We ended up deploying them (union and non-union personnel) on different segments so they didn't have to rub elbows on the same build stand," said Vince Bilardo.

Manufacturing

As the project progressed from its Preliminary Design Review (PDR) through its Critical Design Review (CDR), there was still a need to reconfigure the manufacturing organization. In July 2007, Therese Griebel returned to Glenn from an assignment at Raytheon Missile Systems and joined the project just as it was preparing to cut its first piece of flight material. The dynamics on the shop floor presented Griebel with the same kinds of team building challenges that her colleagues had dealt with from the outset. Personal chemistry was critical.

Griebel found that one shift was underperforming relative to other, which required moving personnel to create a more productive environment. Part of the solution was assigning a new fabrication team lead who had spent most of his career as an instrument maker. "It (fabrication) is not his core trade, but he can fabricate, he knows how to lead and motivate people, and he has the drive to successfully complete things," Griebel said.

On an organizational level, the manufacturing unit, which resided within the Engineering Directorate at Glenn, needed a structure that reflected its newly required capabilities. Griebel led a reorganization that set up the Manufacturing Division to include manufacturing engineering, previously not part of the Division. She also identified and removed individuals who were disruptive to the progress required, and re-assigned individuals who were not getting results due to a poor fit of their competencies with the job they were performing, finding better fit functions for them where they contributed greatly. Additionally, she set in place technical leads in each journeyman technical area, allowing for continued technical expertise on the shop floor with leadership responsibilities. “All of these changes significantly contributed to establishing a team that worked successfully toward a common goal," Griebel said.

(END PART I)

Teaching Notes

This case study has been designed for use in a classroom setting. Please read the full case prior to in-class discussion to allow ample time for analysis and reflection.

Consider the following questions:

- How did the organizational context at Glenn Research Center shape the project manager's challenge?

- What strategies and tactics did the project team leaders employ to help build the right team? How would you differentiate between the strategic and tactical teambuilding decisions?

- What role did professional development activities play in the makeup of the final team?

Ask participants to discuss in small groups, encouraging them to draw analogies to their own experience and develop as many interpretations as possible. The small groups will then reconvene as a large group and share their conclusions.

Epilogue: Getting Smarter

As the fabrication work progressed, the design was not finalized, which created difficulties. "The objective is to complete a design through CDR (Critical Design Review), have your procedures, and have those procedures reviewed and approved before they go to the floor so that everything runs smoothly," Griebel said. In this case, due to the extremely short schedule for the entire project implementation, it was nearly impossible to optimize the flow of design and fabrication activities at a top level. It required daily meetings to optimize what could possibly be done in the immediate near term based on available procedures, materials, and personnel. "It's just not ideal—and it's the nature of the beast," she said.

Vince Bilardo reflected on the difficulties his project had encountered as it entered the home stretch of fabrication before preparing to ship segments to Kennedy Space Center for integration and test. "About two-thirds of our (cost) growth is due to requirements and scope growth, and events outside of our IPT (integrated product team), and about one-third has been within our control and really attributable to what I would call 'maturing estimates.' There are things that you now put in your budget that you couldn't have guessed that you needed. Or you did guess at it, and you guessed low, because you weren't smart enough. You just get smarter over the course of the project."

On October 24, 2008, the Glenn team shipped the Upper Stage Simulator down the Ohio River on the first leg of a twelve-day journey that would transport it to Kennedy Space Center for integration and testing.