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SPACE WARFIGHTING CONSTRUCT

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Something unusual happens when you expand your vocabulary. The simple act of learning a new word or phrase somehow makes that word or phrase ubiquitous. What had been unknown suddenly appears everywhere. The Space Warfighting Construct is like that. Just a few months ago, the term was rarely heard; now it seems to crop up in every conversation. My hope is that this short article can be an aid to orient your focus to this important domain and to translate the vital work you are doing to better align with this critically important enterprise model.

The Space Warfighting Construct is a comprehensive approach comprising several core parts: the Space Enterprise Vision, the Space Warfighting Concept of Operations (CONOPS), and the Space Mission Force, all supported by a resilient architecture, enterprise agility, and strategic partnerships.

Vision. The Space Enterprise Vision, which was jointly adopted by the Air Force and the National Reconnaissance Office (NRO), charts a path to a resilient space enterprise by 2030. The primary goal is to prevent aggression through deterrence but also to prevail in any conflict that extends into space. The vision requires the space community to rethink assumptions about the sanctuary state of space and to view the space domain the same as any other warfighting domain. Overall, it is focused on ensuring that the advantages our warfighters derive from space will be there when needed.

Concept of Operations (CONOPS). The United States has traditionally enjoyed uncontested freedom in space. As a result, the command structure evolved to be stovepiped and uncoordinated, with mission approaches tailored to meet individual system needs. Little thought went into the capabilities and connections that might be needed if the environment grew contested. The Space Warfighting CONOPS seeks to establish the space

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Chart courtesy of Air Force Space Command. Key: C2—command and control; SSA—space situational awareness; I&W—indication and warning; CONOPS—concept of operations; DOTmLPF-P—doctrine, organization, training, materiel, leadership and education, personnel, facilities, and policy; IC—intelligence community; USG—U.S. Government

FIXED-PRICE CONTRACTS: COST CONTROL AND ACQUISITION SUCCESS

By MARTHA D. CALLAWAY and SUSAN E. HASTINGS
The Aerospace Corporation

A recent Aerospace study shows how fixed-price contracts can contribute to acquisition efficiency and improved cost control. Fixed-price contracts for major systems acquisitions have gained favor with the expected benefits of known price, limited government liability, and reduced cost growth. However, these benefits may not be achieved and may be accompanied by unintended consequences, such as higher initial price and high-priced contract modifications.

Based on a literature search and interviews with program managers of space systems using fixed-price contracts, the study revealed the following:

- **High Initial Price.** Limiting customer liability via fixed-price contracting can drive the initial price up due to the price paid for risk, especially with moderate or high risk.
- **Similar Overall Cost Growth.** While incentive fee contracts experience less cost growth across the DOD, firm, fixed-price contracts experience at least as much cost growth as other contract types.
- **High Price of Modifications.** Modifications to fixed-price contracts are more expensive than they are for cost-plus contracts.
- **Correlation with Risk and Lifecycle Stage.** Across the DOD, fixed-price contracts used for full-scale production in low-risk situations have less cost growth than cost-plus contracts used for development or than in other high-risk situations—but this correlation does not mean fixed-price contracts cause reduced cost growth; rather, it means fixed-price contracts used in the right situations experience reduced cost growth.

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WHOOPS! MANAGING ERRORS IN SPACE SYSTEM MANUFACTURE

By LAURIE STUPAK
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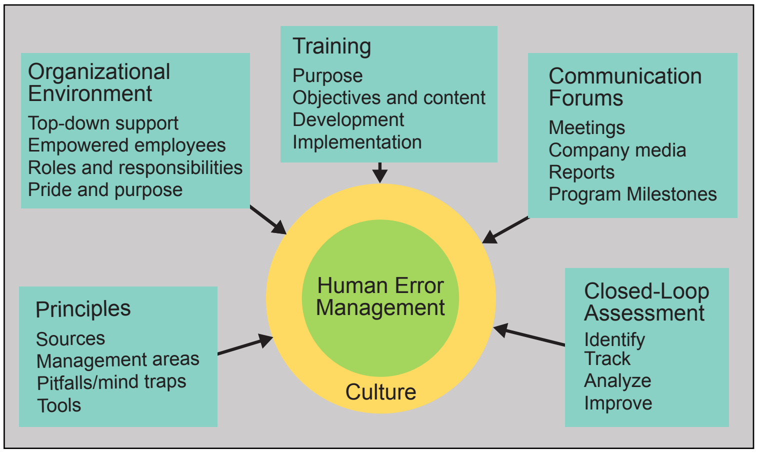
To err is human—especially when it comes to producing space hardware. More than 50 percent of manufacturing errors are caused by human error. Given the extreme complexity of space systems, mistakes are inevitable. But if they cannot be prevented, can they at least be mitigated?

A task group at the Mission Assurance Improvement Workshop sought to answer that question. Based on a review of real-world mishaps, the group produced a compilation of best practices that could help to manage human error in space system production and testing. These best practices fall into five categories: Principles, Organizational Environment, Training, Communication Forums, and Closed-Loop Assessment.

Human-error management starts by establishing core principles, which reflect sources of error as well as the systems and tools in place to address them. Effective error management requires an effective organizational structure, with top-down support and clearly defined roles and responsibilities. Moreover, each employee must feel personally empowered and motivated by a sense of pride and purpose.

Training is, of course, a fundamental part of error prevention and mitigation. Training must be rooted in the core principles and reflect the specific needs and culture of the organization. Similarly, communication is essential. An error-management program should include forums to support continual training, disseminate information, share metrics, and foster open discussion about incidents. Communication forums can encompass numerous venues, such as corporate media, meetings, reports, and milestone reviews. Finally, any serious effort to manage, prevent, and learn from human errors should include a process to identify, track, and analyze them.



Ultimately, effective error management is a function of the corporate culture. In particular, the culture should foster both individual responsibility and collective awareness. Employees need to be aware of complacency and overconfidence, and recognize their own potential for error. When a mishap does occur, management must focus on the error itself, and not seek to place blame. The concept of error avoidance must be fully ingrained; that includes sharing errors and lessons learned throughout the organization.

Error incidents can never be completely prevented—but a proactive error management culture can reduce their frequency and effects. In the long run, a proactive approach is more efficient and effective than a reactive stance.

Reference

TOR-2017-01691, *Best Practices—Human Error Management*

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FIXED-PRICE CONTRACTS: COST CONTROL AND ACQUISITION SUCCESS

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When do fixed-price contracts contribute to acquisition success? How should fixed-price contracts be managed to reduce cost growth and enhance acquisition success? The answer involves two factors: using the appropriate contract type, and appropriate contract management.

When should you use a fixed-price contract, especially a firm, fixed-price contract?

First, you need a low-risk production effort with no anticipated changes. Low risk includes having clear and stable requirements, mature technology, mature design, and proven manufacturing methods.

Having technical baseline stability decreases the chance of late, high-cost perturbations. Changes are anticipated when it is known that the requirements and design are not firm, but may also be anticipated when the request for proposal is not clear and unambiguous.

So not only must requirements and design be stable, but the request for proposal should also be well-planned, realistic, complete, and well-written, without gaps.

Second, you need a firm basis for pricing. This means you have already built at least one unit and know the actual cost of building it before entering into a fixed-price contract.

The figure on the next page compares a possible FFP contract (blue lines and bars) to a cost-plus fixed fee (CPFF) contract (green lines and bars) for the same hypothetical, medium-risk effort. The variation of the government's payments as actual costs (grey) fall above or below the contract's target cost. In this case, the FFP price includes a 20-percent risk margin, so its overall price to the government is higher—unless the CPFF contract has a very large overrun.

Presuming you are using a fixed-price contract under the right circumstances, how do you manage it to encourage success? While managing a "cost-plus" contract is based on oversight and direction, managing a fixed-price contract is based on insight and influence. Therefore, developing trust and good working relationships are more important for fixed-price contracts than for cost-plus contracts, and the program office uses that trust to develop its management in four areas:

- **Technical Baseline.** Commitment to the technical success of the program requires focus on mission success and technical execution, and avoiding distractions.
- **Sociopolitical Issues.** Stakeholder commitment is required to define mission requirements, objectives, and performance goals—and to keep the program sold.
- **Contractual—Managerial Issues.** Program success requires a qualified

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LESSONS LEARNED FROM A LAUNCH FAILURE

Test the specific configuration that will be flown

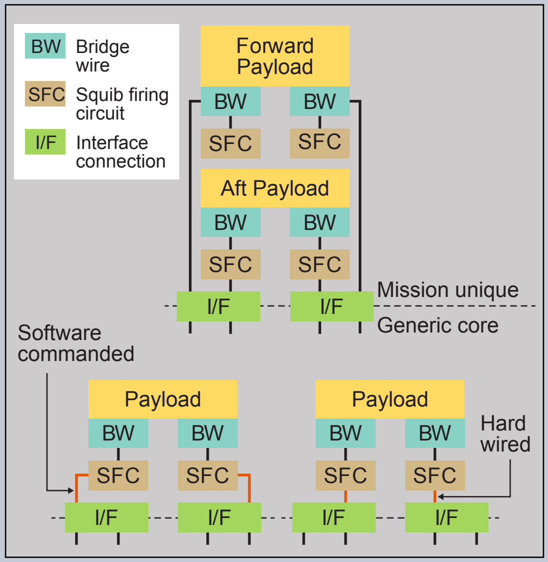
By PAUL CHENG
The Aerospace Corporation

A miswiring prevented a satellite from being deployed.

Cause of the Anomaly

The mission specification had the separation commands sent to the "forward" position. An engineer redlined the commands to "aft" to simplify wiring but unfortunately this change was not incorporated in the final mission specification.

Not realizing that the informal redline had fallen through the cracks, the hardware group designed an incompatible harness. The drawings were released as a new baseline, making it difficult to detect crucial changes. Several systems engineering departments could have checked the compatibility of the final design to overall requirements, but none did—the key mission specification was developed by software engineers and was not placed under systems engineering's jurisdiction.



Separation configuration: (top) for two payloads; (bottom) for the failed mission

Why was the mistake not discovered on the ground? Because the generic systems test activated both positions, allowing the miswired ordnance verification unit to appear to be working.

Lessons Learned

- Systems and software engineering should actively coordinate.
- Conduct tests and reviews to validate that the requirements are met, rather than that the drawings are correctly implemented.
- Actively involve systems engineers in software development activities, and formally control all (including software) interfaces.

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FIXED-PRICE CONTRACTS: COST CONTROL AND ACQUISITION SUCCESS

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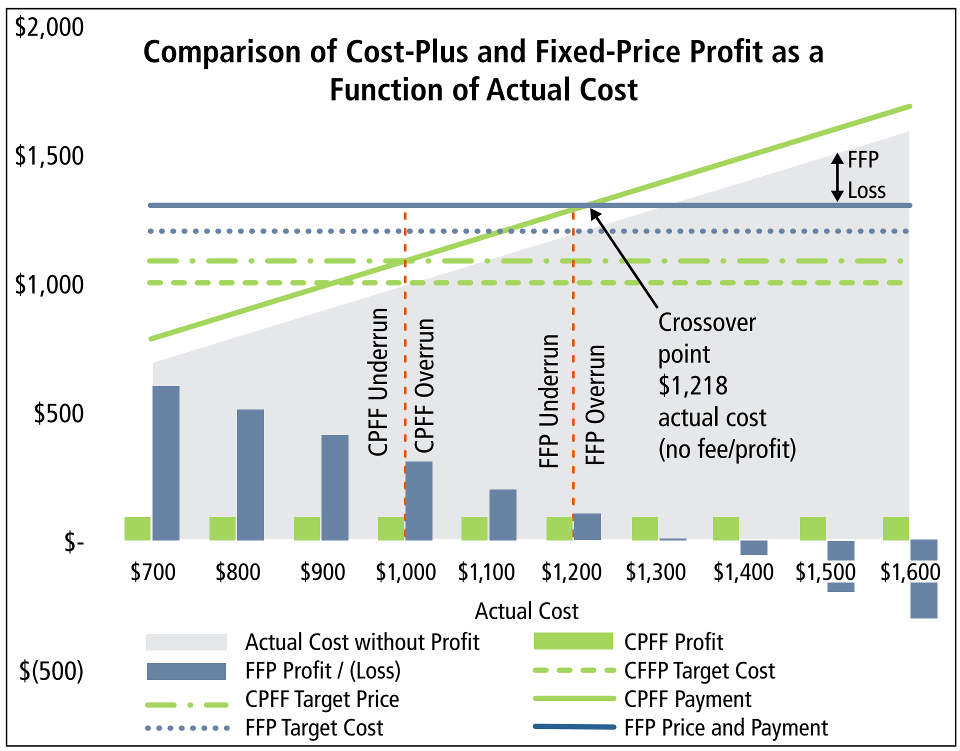
team, executable program schedule, cost realism, budget stability, and development/use of good incentives.

- **Overall Program Orchestration.** The goal is to strike a balance among the technical baseline, sociopolitical issues, and contractual–managerial issues. The program manager must look objectively at the acquisition issues and political realities surrounding a given program, know the acquisition environment, and cultivate a constructive relationship with higher headquarters to achieve this balance.

Reference

TOR-2017-01564, *Acquisition Guidance for Affordability Overview: Using Fixed-Price Contracts as a Contributing Tool for Successful Cost Control Presentation*

For more information, contact Martha D. Callaway, 571.307.3919, martha.d.callaway@aero.org, or Susan E. Hastings, 571.307.3871, susan.e.hastings@aero.org.



This figure compares a possible firm fixed-price (FFP) contract (blue lines and bars) to a cost-plus fixed-fee (CPFF) contract (green lines and bars) for the same hypothetical, medium-risk effort. The variation of the government's payments as actual costs (grey) fall above or below the contract's target cost. In this case, the FFP price includes a 20-percent risk margin, so its overall price to the government is higher—unless the CPFF contract has a very large overrun.

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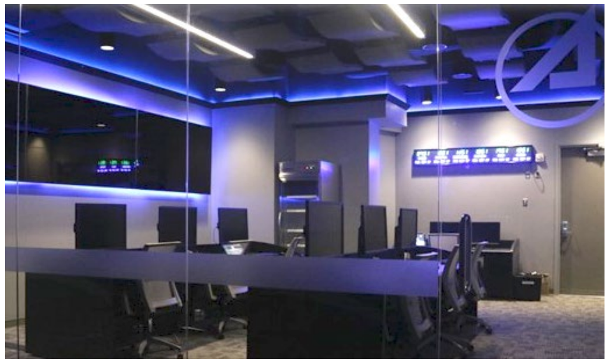
situational awareness and command and control needed to deter hostile action while enabling U.S. forces to fight through a conflict.

Mission Force. Many facets of the Space Warfighting Construct are abstract in nature, but the Space Mission Force involves real people with real operational needs. A new generation of space operators must be trained and equipped to overcome an adversary that can think, respond, and adapt. The engineering-focused approach must give way to improved operations and autonomy to counter rapidly evolving threats.

Resilient Architectures. The Space Warfighting Construct will require a reevaluation of the decisions and objectives that gave rise to the current space architecture, which favors the aggregation of similar missions to minimize cost. Though this approach seemed prudent in the past, it lacks the flexibility and robustness to address the coming threats, challenges, and opportunities in space. Large spacecraft tend to accrete complexity, resulting in long integration cycles with slow technology turnover. In an increasingly contested and rapidly evolving domain, long and slow acquisition cycles simply will not cut it. We will need to pull out the full toolset of resilient options and combine them to create a cohesive and connected architecture that can reliably deliver needed warfighting capabilities.

Enterprise Agility. As risk timelines change or new risks emerge, different system elements will need to react quickly and decisively. The entire enterprise must have the doctrine, organization, training, materiel, leadership, personnel, facilities, and policy in place to enable such rapid response. This overall agility will be critical to both the space and ground system elements.



Aerospace's Space Analysis and Collaboration Center features unique data sources and processing capabilities that enable government, FFRDCs, and industry to come together to solve complex Space Warfighting Construct challenges.

Partnerships. Access to space continues to get cheaper and easier, and a vast array of government, commercial, and educational entities around the world are designing and launching a new generation of satellite systems. This proliferation presents a growing challenge for the national security space enterprise; but it also presents an opportunity to extend the reach and capacity of critical space missions. The Space Warfighting Construct recognizes the growing importance of new space participants and seeks to leverage the collective expertise of the extended space community, at home and abroad, to realize the full benefits of this comprehensive paradigm.

As you learn more about this new phrase—the Space Warfighting Construct—you may start to view your work in a different light—and perhaps consider new ways that you can contribute to one of the most exciting and important goals that our customers have articulated in decades. This vision will further influence how we view mission assurance with respect to those broader definitions of all the activities and measures taken to ensure that required capabilities and supporting infrastructures are available to the DOD to carry out the National Military Strategy. This is truly an exciting time to be in space.

RECENT GUIDANCE AND RELATED MEDIA

Value Proposition for Mission Assurance by T. Nygren; TOR-2017-00688; OK'd for public release

Joint Mission Assurance Council (JMAC), 7 September 2017 by G. Johnson-Roth and D. Phillips; TOR-2017-02698; OK'd for USG

ASIC and FPGA Circuitware Development Standard for Mission-Critical Systems by C. Sather; TR-RS-2017-00027; OK'd for USGC

Existing Standards as the Framework to Qualify Additive Manufacturing (AM) of Metals by M. O'Brien; TOR-2017-01880; OK'd for public release

Acquisition Guidance for Affordability Overview: Using Fixed-Price Contracts as a Contributing Tool for Successful Cost Control Presentation by S. Hastings et al.; TOR-2017-01564; OK'd for USGC

Best Practices—Human Error Management by I. Palusinski and B. Valant-Spaight; TOR-2017-01691; OK'd for public release

Improving Mission Success of CubeSats by C. Venturini et al.; TOR-2017-01689; OK'd for public release

Evaluation Guide for Space Program Independent Program Assessments (Update) by C. Donahue et al.; TOR-2017-01096-Rev A; OK'd for USGC

MIL-PRF-38534 Hybrid QML Status, SPWG 2017 by J. Sokol; TOR-2017-01486; OK'd for public release

Mission Assurance Considerations for Model-Based Engineering for Space Systems by M. Wheaton; TOR-2017-01695; OK'd for public release

Technical Assessment of CubeSats Subject to Long-term On-orbit Storage by A. Darley and B. Rogers; TOR-2017-01326; OK'd for USGC

Effective Thickness Concept for BME Capacitor Reliability by J. Scarpulla; TOR-2016-03136; OK'd for public release

Thin MLCC (Multi-Layer Ceramic Capacitor) Reliability Evaluation Using an Accelerated Ramp Voltage Test by J. Scarpulla; TOR-2016-03138; OK'd for public release

Application Guidelines for Unit Climatic Tests Section of TR-RS-2014-00016, Test Requirements for Launch, Upper-stage, and Space Vehicles; Part C: Climatic Exposure Tests: Humidity, Sand/Dust, Rain, Salt Fog, Fungi, Ozone, and Hail and Foreign Objects Tests by M. Easton et al.; TOR-2016-02926; OK'd for public release

Tailoring of IEEE 15288.1: Specialty and Systems Engineering Supplement by B. Shaw; TOR-2015-01949-Rev A; OK'd for USGC

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USGC = Approved for release to U.S. Gov't Agencies and Their Contractors

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FALL/WINTER/SPRING 2017–2018

Nov 28–29 *Space Resiliency Summit, Alexandria, VA*

Dec 5–7 *SpaceCom, Houston, TX*

Jan 8–12 *SciTech Forum, Kissimmee, FL*

Feb 5–8 *SmallSat Symposium, Silicon Valley, CA*

Apr 9–12 *Earth and Space 2018, Cleveland, OH*

Apr 16–19 *Space Symposium, Colorado Springs, CO*