

**Government Insight/Oversight for Commercial Crew Transportation**  
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**Introduction**

When the NASA Administrator announced the Commercial Human Spaceflight initiative on February 1, 2010, he said “I give my word that they [commercial human spaceflight missions] will be safe.” This builds upon the report of the Review of US Human Spaceflight Plans Committee (aka, the “Augustine Committee”) which declared in October 2009 that “throughout this report, safety is treated as a sine qua non [the indispensable thing]” as well as associated multiple verbal comments at public meetings that NASA must make these systems safe. These statements of principle, then, define the extent to which NASA will require insight and oversight for the transportation of government personnel to low earth orbit by commercial entities. NASA is required to validate that the flight vehicle, its systems, the operating conditions including design environments, mission planning and execution, flight crew training and ensure other organizational processes are safe and result in a high confidence that each mission will be successful. While other models might be proposed which have a different role, this stated philosophy will set the basis for NASA’s requirements, workforce, and role in commercial human spaceflight.

This white paper explores the probable model for government insight and oversight to commercial crew transportation to low earth orbit. It provides recommendations for the right balance of civil servant workforce insight/oversight that will contribute to the safe flight and safe return of NASA crew members on commercial contract vehicles.

Before getting into specifics, it is important to define what is insight and oversight. There are a myriad of definitions and perceptions of these terms internal and external to NASA so we need to be clear on this. Insight is defined as the capacity to discern the true nature of the project’s efforts to design, develop, test and operate the vehicle system. It is NASA’s ability to penetrate into the commercial crew provider’s processes and their vehicle design, development, test and operations in an effort to human rate the vehicle and to improve the safety of operations and mission success. Oversight is the watchful and responsible care and management of the commercial crew development, test and operations efforts. This is accomplished through overseeing the performance of the provider’s vehicle design, development and test efforts and their ability to certify their vehicle for safe human transportation. The primary elements of oversight require government approval and/or direction.

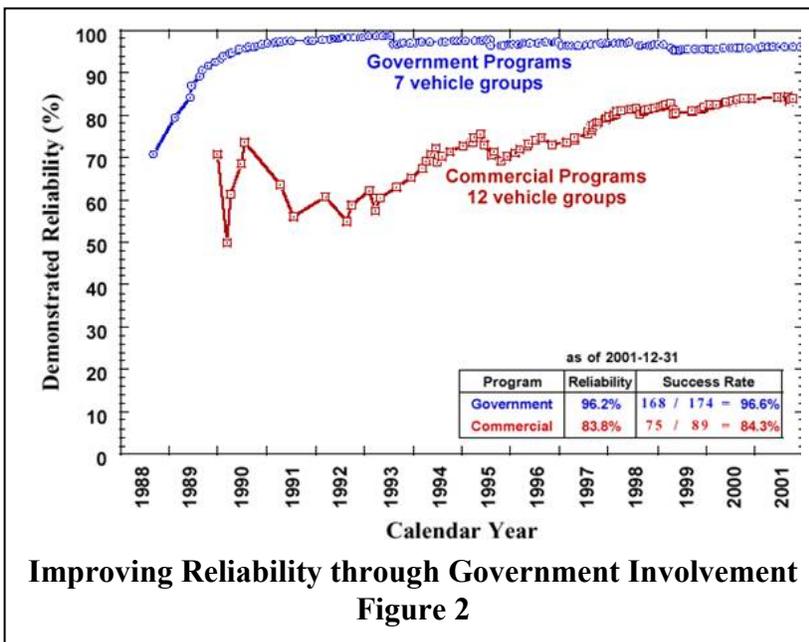
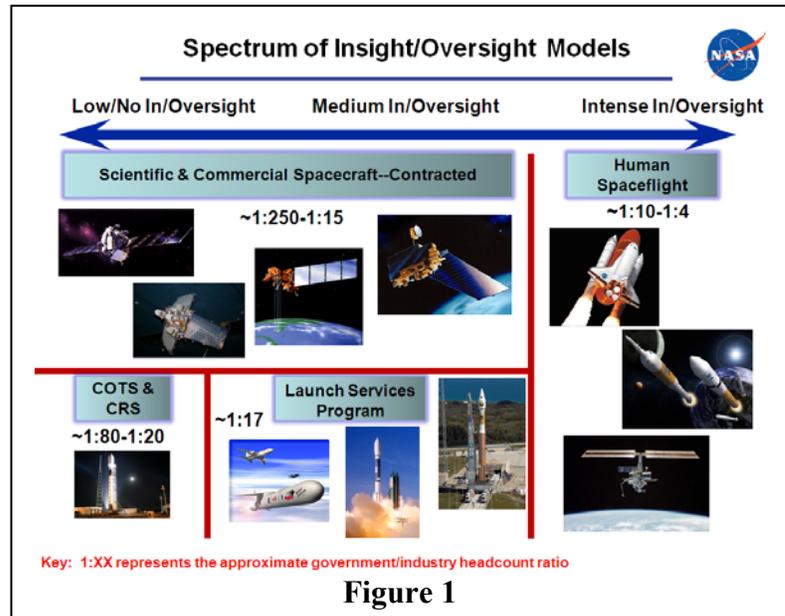
Determining the level and depth of insight/oversight performed by NASA on the commercial crew development partners will be crucial in whether these commercial ventures are successful and whether the partners have designed a vehicle that is safe and reliable for NASA personnel to fly on. The approach taken to develop the appropriate commercial crew insight/oversight model was to survey different insight/oversight models, including those used to support the Human Spaceflight Program, the Launch Services Program, robotic spacecraft developments performed

by contractors, the COTS program and commercial spacecraft developments. As part of this study, the following key issues were addressed: Technical Authority Engagement, review team requirements, FAA engagement and “Taxi” versus “Rental Car” type contracts. A nominal government insight/oversight engagement strategy was developed with the capability for “surge” engagements during key decision milestone reviews and to resolve critical design, development, testing and operations issues through government/industry problem resolution team partnerships.

### NASA’s History of Insight/Oversight Engagement

In its 50 years as a space agency, NASA has utilized a wide spectrum of insight/oversight models for its out-of-house or contracted vehicle developments. See figure 1. These models include virtually no insight/oversight or very little insight/oversight, on one end of the spectrum to intense insight/oversight, primarily for human spaceflight vehicles on the other end of the spectrum.

Several NASA and Department of Defense studies have shown that vehicle/mission success is maximized through a strong industry-government insight/oversight partnership. See figure 2.



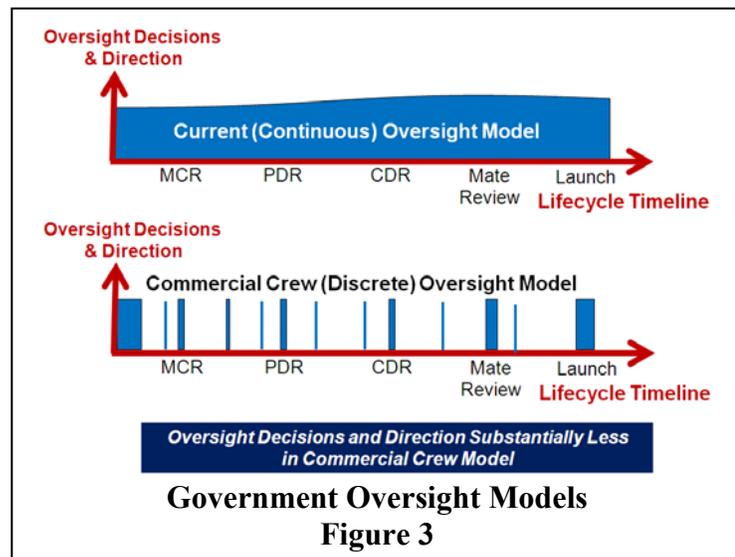
During the 1990’s the aerospace industry adopted a Faster-Better-Cheaper philosophy, which resulted in the implementation of a very low/no insight/oversight model for robotic spacecraft and launch vehicles. The faster-better cheaper philosophy resulted in several back-to-back spacecraft and launch vehicle failures. There were many lessons learned from these experiences as are illustrated in the Broad Area Review reports from the DoD, the Mars Climate Orbiter Mishap Investigation Reports and the Faster-Better-Cheaper

Task Force Report. Therefore, it is crucial for NASA to choose a commercial crew model that will maximize mission success while not unduly impacting the partner's ability to get the job done efficiently and in a cost effective manner. This "sweet spot" is the insight/oversight model proposed herein.

This paper proposes a change in the way government and commercial providers interact for human spaceflight missions. In previous human spaceflight programs, the government (NASA) had total oversight responsibility: all major decisions were made by NASA management; all the details of the design, development, testing, production, and launch preparation were under the close scrutiny and cross-check by NASA civil servants who maintained ultimate decision authority in all matters. The model

proposed herein assumes an insight/oversight partnership between the NASA civil servants and their industry providers. From an insight perspective, this means that the government team (NASA civil servants and contract support personnel) will closely follow the design development, integration, and testing of the vehicle. And the production practices of the provider and subsequent operations of the flight system. They will become key members of the overall commercial crew provider team and will be expected to spend substantial time embedded in the provider's facility. As embedded team members, individuals are expected to

become trusted team members that can bring value-added ideas and experiential-based knowledge into the provider's design, development and testing efforts. Through this process, they will gain significant insight into the provider's vehicle system and they will have early insight into any issues or concerns that could impact vehicle safety. And they can make recommendations to the industry partner and the government oversight team to improve the vehicle design or correct a known issue/defect. But to be clear, final Oversight decisions on high-expense or contentious recommendations will be performed by the NASA commercial crew Program leadership on the government side and the project leadership on the commercial (partner) side. As compared to the continuous oversight control employed previously, the government team will have discrete oversight control, making decisions only when absolutely necessary. See figure 3. Many of these discrete oversight decision points will be known and negotiated prior to startup, but some will be unplanned direction to improve vehicle reliability and crew safety. This includes decisions on bringing in an additional cadre of team members to resolve issues. This approach will optimally balance safety and mission success priorities with design, development and operations costs through an insight/oversight approach that is not over-burdensome.



## **What is included and what is excluded from this study**

### Included in this study:

Technical engineering and production insight provided by the agency engineering directorates of the various centers. This includes the institutional support contractors for these agency directorates (e.g., Jacobs). Only when necessary, this may include certain test facilities, labs, computer systems, and other tools to perform independent analysis and testing or modeling and simulations; these facilities and their support work force would be pro-rate charged to the technical insight/oversight function. In addition, the Program and Project office set up to administer this effort are included in this model.

All functions of an operations concept required to make a mission successful, including mission control, mission planning, and crew training functions. The primary responsibility of these functions will probably not reside with the government, according to the ops concept for commercial crew services, however there may be provisions for the provider to purchase such ops services from the government. Similarly, use of governmental network services (e.g. TDRSS or GSTDN) may be purchased by the provider from the government if they so elect.

Safety insight is provided by the agency safety and mission assurance directorates of the various centers. This includes the support contractors for these agency directorates (e. g., SAIC) and also includes the workforce provided as direct support by the DCMA for safety and quality assurance monitoring. Included in this function are the management, secretarial, and administrative heads which make these organizations functional.

### Excluded from this study:

Center management and operations and the ancillary support which makes NASA work. This is not a full cost accounting exercise. NASA HQ is, by definition, not included in this estimate.

Procurement, legal, contracts, business administration, their support contractors are not included in this report. The requirements for these offices are set by Federal Acquisition Regulations and pertinent Federal Laws. Procurement and contract monitoring will not be affected by any change in model of NASA technical insight/oversight, or more precisely, the assumption is that any changes will be minor. This includes headcount for that part of DCMA that NASA uses for contract/business monitoring.

Work done by other Federal or state agencies (e.g., FAA, OSHA, IRS, Dept. of State, etc.) is not included. This report is limited to the NASA workforce in direct insight role to the commercial crew transportation provider.

GFE production of any equipment for use in the commercial crew vehicle is not included. Since this is undefined until award time, there is no way to estimate it. However, it will add to the government resource requirements and budget. Even if the GFE is acquired from third party

vendors, this will still be true. Currently a significant portion of the ISS vehicle project office civil servant work force is performing GFE production for example.

Technology development or maturation performed by government labs or engineering design and test facilities. This is undefined until award time; there is no way to estimate it, but can be provided to the partners on a reimbursable basis. Currently this is a significant portion of the Constellation program government work force. This is not government insight (or oversight) in any event; this is what is sometimes necessary and provided by the government for a provider to succeed in completing a developmental high tech product.

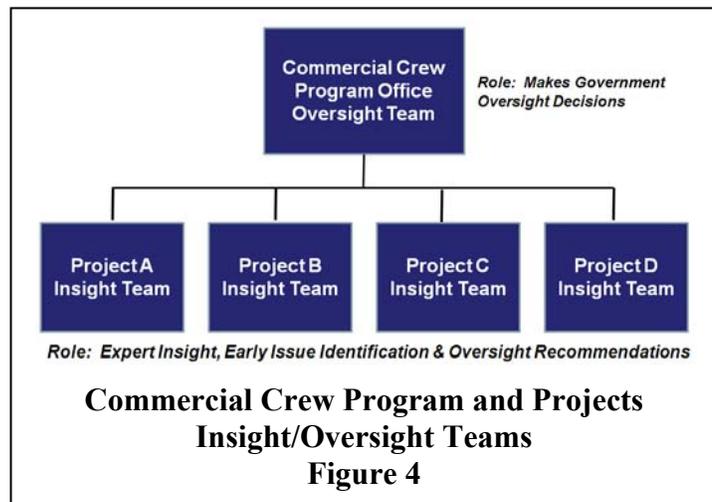
Finally, NASA will adopt the safety assessment role only for government procured services. NASA has not been authorized regulatory powers by the Congress or the Executive branch to perform safety assessment or regulatory authority over non-government procured human space flight (e.g., space tourism).

### **Insight/Oversight Technical Engagement Overview**

The driving requirement of all human spaceflight vehicles is to ensure the safety of the NASA crew and the safety of those operating or within the vicinity of the vehicles. Strong leadership on the NASA and commercial side is a key tenet in this partnership----they will assure that this safety requirement is met. For each project, it is crucial that NASA and the commercial crew contractors select outstanding, communicative Project Managers, lead systems engineers, lead safety officers and systems engineering teams. Individuals that put the team first, have outstanding, in-depth experience in hardware and software development, test and vehicle operations, and individuals that can make challenging, risk informed decisions with a keen eye on safety.

The insight/oversight approach recommended is to utilize the technical expert engagement and technical reach-back approach that has been successful in the Launch Services Program, the robotic spacecraft projects and the COTS advisory team. And to use the NESC approach of bringing in problem resolution team experts to quickly resolve major issues when needed.

The NASA insight/oversight team is composed of two crucial entities. See Figure 4. The first is the Program Office leadership team, detailed in Figure 5, which provides strategic guidance to all the commercial crew projects and makes the oversight decisions based on recommendations from the project insight team. The second is the project-specific insight team, detailed in figure 6. They are responsible for gaining insight into the contractor design, identifying issues and concerns early, and making oversight recommendations.



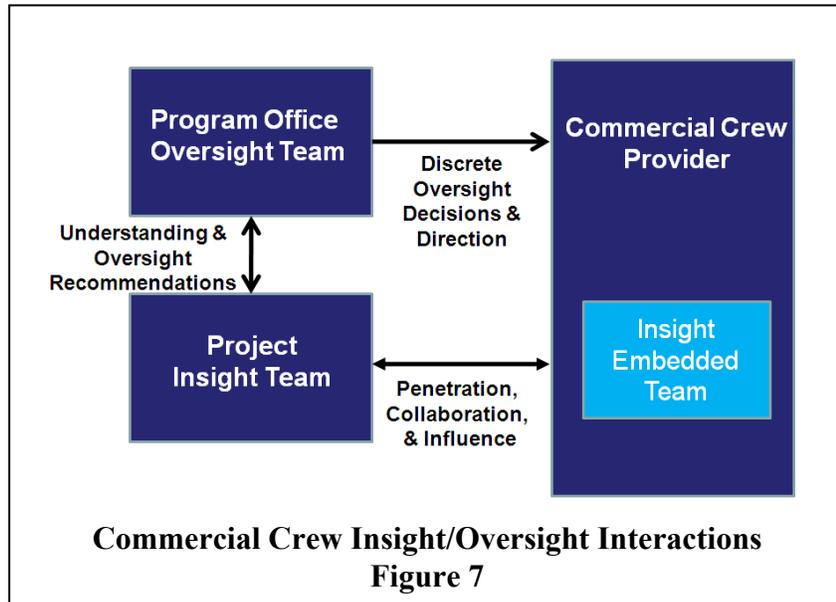
The project insight leadership team consists of the commercial crew project executive (manager), the lead systems engineer (who serves as the project chief engineer), the lead safety and mission assurance engineers (who serves as the project chief safety officer) and representatives from the Crew Office, ISS Program Office and the FAA. The leadership team, coupled with a cadre of systems engineers and subsystem experts, represent the sustaining members of the project's insight team. This core team will closely follow the design, development, test, verification and operation of the commercial crew vehicles.



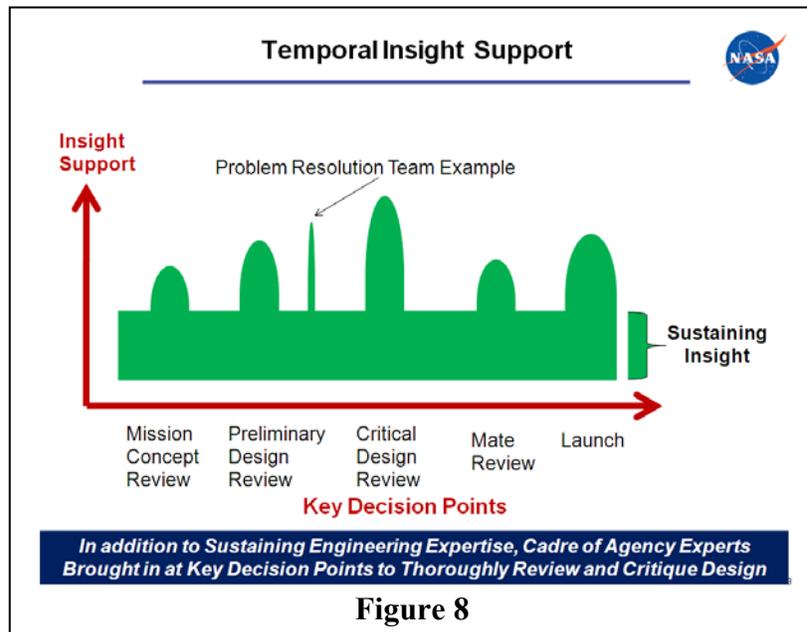
An effective and highly recommended method of improving product reliability, safety, quality, and even efficiency is to have long term, on site resident government civil servants embedded in a vendor facility. Figure 7 represents this overall insight/oversight model. This is certainly the experience of the NASA Launch Services Program which acquires launch vehicles and their associated services for robotic missions. On site resident civil servant presence at the provider's major locations is a critical element in the success of the NASA Launch Services (NLS) contract and launch services program. The development of interpersonal relationships and the trust which goes along with daily interaction yield significantly greater insight than periodic anonymous crowded reviews where there is little interpersonal interaction. The development of a rich and deep understanding of a product and the processes which are used to produce it will yield significantly more powerful and creative suggestions and improvements from the government officials involved. Open access to the production line, problem reporting systems, informal and formal meetings on a daily basis are much more effective than an auditorium full of reviewers who work on multiple projects. This insight approach is in-line with the way NASA successfully built and flew the Mercury, Gemini and Apollo human spaceflight vehicles. And it is in-line with the way the "best of the best" robotic spacecraft developments are built and operated.



As illustrated in figure 8, the insight support will include the sustaining engineering expertise, described above and an additional cadre of agency experts that will provide temporal support to the program during key decision points or when a major design/development/test issue arises. The core, sustaining team members will closely follow the vehicle design, development, test and verification. Additional experts will be temporarily assigned, from the institution and the NESC during major review and test periods to thoroughly critique the system and provide recommendations and guidance to the sustaining project team members and the program. Also, if a major issue arises, a partner-government problem resolution team will be temporarily stood-up to understand the issue, develop a corrective action plan and ultimately resolve the issue as expeditiously as possible.



The ramp-up and ramp-down of agency experts to support the project's key milestone reviews and problem resolution teams is an essential aspect of the insight model. It will require close collaboration between the NASA program/project offices and the agency institutional expert pool and the insight resources will be vigilantly controlled by the program office. It will require prioritization of the work of the experts, to ensure they are available when problems arise or during the milestone reviews. There are many good, agency examples of this type of approach working well, including examples in the human spaceflight community, in the Launch Services Program and at the Robotic Spacecraft field centers. The best example of how this model has worked for the good of the agency is the outstanding efforts of the NESC, where experts are constantly ramped into and out of various efforts depending

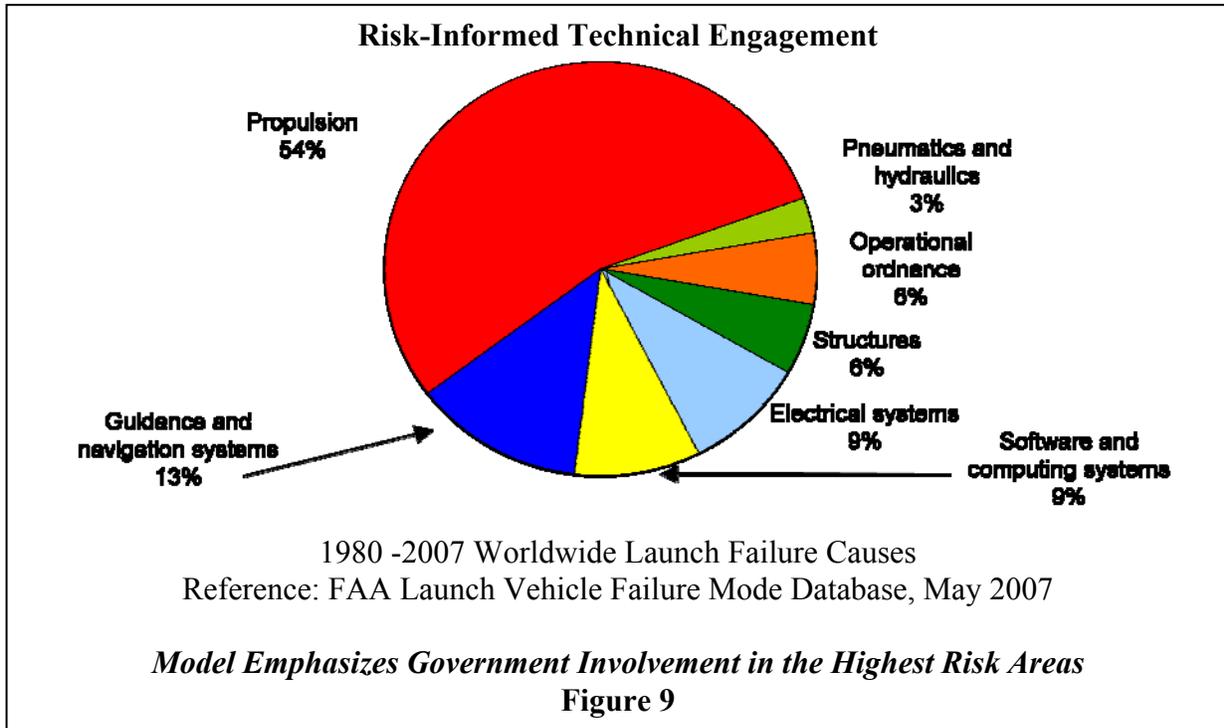


upon agency priorities and the issue at hand. This approach, of engaging a sustaining core team with the temporal team, will result in a more efficient use of government experts, it will significantly reduce the government marching army, and it provides an optimal government-industry partnership.

The scope and amount of government personnel assigned to support insight/oversight for specific commercial crew providers will vary and is dependent upon a number of factors. Clearly, less experienced human spaceflight providers will require more government involvement than those that have a substantial, successful history in human spaceflight development. Those partners that propose a system with a long successful history of comparable launches will require less insight/oversight than those that propose a brand new vehicle. Government insight/oversight will also be dependent upon the strengths and weaknesses of the proposed design and that of the provider team.

### Risk-Informed Subsystem Engagement

The project leadership team will engage the insight subsystem experts based on perceived vehicle risk and historic failure modes. They will adjust the strength and depth of subsystem expertise, based on historical data from launch vehicle failures and other understood or perceived risks. As shown in figure 8, this data illustrates the need for more government expertise in high risk areas, such as propulsion systems, avionics systems, software systems, electrical systems and guidance navigation and control systems. In addition, based upon previous human spaceflight experience, an in-depth government understanding of abort systems, crew systems, separation systems and parachute systems will improve the vehicle risk posture. To ensure consistent insight across the various commercial crew projects, the NASA team will develop a set of pre-declared independent analysis verifications and test verification reviews that will be performed by the insight team. This is similar to the approach used by the Aerospace Corporation to verify a vehicle for each Air Force Launch. Figure 10 depicts an example composition of the overall project insight team that will accomplish these roles.



Technical Authority Engagement

As shown in figures 5 and 6, the program and project technical authorities and the internal and external office representatives are matrixed from their home organizations and are embedded, co-located in the program or project organization. For the project, the engineering technical authority serves as the leads systems engineer. The cadre of technical authorities and the office representatives serve as the NASA project systems engineering team leadership. In addition to their systems engineering leadership duties, the technical authorities will be the agency stewards of the NASA requirements and standards that will be imposed on the commercial crew vendors. They will also work with the program, projects, vendors and institution to tailor these requirements and standards, as appropriate.

**Leadership Team:** Project Executive, Lead Systems Engr, Lead Safety & Mission Assurance Engr, Reps from Crew Office, ISS Program Office, and FAA

**Core Team:** Systems Engineering Team  
**Subsystem Experts:** *Risk-informed concentration*—Abort systems, Launch Vehicle Propulsion, GN&C, Avionics, Software, Electrical, Crew Systems, Parachute Systems, Separation Systems; *Nominal Concentration*—Aerosciences, EMI/EMC, Flight Mechanics, Flight Testing and Verification, Ground Systems, Human Factors, Life Support, Loads & Dynamics, Materials, Mechanical Systems,/Structures Non-Destructive Evaluation, Mission Operations, Active & Passive Thermal Control, Propulsion – Spacecraft/RCS, Probable Risk Assessment

**Temporal Support Team:** NESG, Commercial Advisory Team, Additional Review Team Advisors, & Tiger Teams, as Required

**Detailed Breakdown of  
Commercial Crew Project Insight Team**

**Figure 10**

## “Rental Car” vs. “Taxi” Engagement

There appears to be no perceivable differences in insight/oversight engagement if the agency decides to procure commercial crew “Rental Car” services, as compared to “Taxi”-type services. The main difference in roles between these two service models is the makeup and use of crew members, which would primarily impact crew training. When one compares the two service models, crew training (separate from technical insight/oversight) is driven by the lifeboat (entry) function, so training costs and manpower are not significant between the two models and insight/oversight is not affected.

### **Assuring Safety and Vehicle Reliability**

NASA and the aerospace community have developed an outstanding complement of design and human certification requirements, rules, and processes that can substantially enhance vehicle reliability, improve mission success, and maximize crew safety. Some examples of these include the NASA Human Rating Requirements (NPR 8705.2); the NASA mandatory engineering standards; safety and mission assurance requirements and standards; design and test rules such as the GSFC Golden Rules; crew health and medical requirements and standards; and NASA Procedural requirements, such as NPR 7120.5 for Program and Project Management and NPR 7123.1 for Systems Engineering. The technical authorities, in concert with the program and project, will define an optimal set of requirements. The intent is to maximize safety and reliability while not overly burdening the vendor, program and project with unnecessary requirements that can significantly and unnecessarily increase the size and scope of the insight/oversight team and run-up development and operations costs.

This analysis also assumes that NASA directives, requirements, and procedures are tailored to fit with this enterprise. As good agency stewards and leaders of the systems engineering team, the technical authorities will work with the vendor, program and projects to tailor the requirements to support the commercial crew service role. Tailoring will include the ability to substitute an equivalent contractor standard, if it exists, or the removal of non-applicable requirements or standards.

Projects will utilize tailored versions of the NASA governance (e.g. NPRs 1000.1, 7120.5 & 7123.1) as key tenets in the design, development, test and operations of commercial crew vehicles. These policies, once tailored, have provided an effective and successful process for maximizing programmatic and technical success of programs and projects through their full lifecycle. They have successfully supported the full spectrum of vehicle developments, from simple, inexpensive robotic spacecraft to complex human spaceflight vehicles. This is accomplished through judicious tailoring of the requirements, to support the specific vehicle development and the insight/oversight model proposed. This also includes the plan to perform key milestone reviews (SRR, PDR, CDR, mate review, etc) and the method used to independently review and critique the system at these milestones.

## **Mission Planning, Crew Training, and Mission Operations**

NASA has a long heritage of operational control over human space flight mission preparation and execution. These elements have been critical to the safety of numerous missions (reference Apollo 13 as only one example). The current Commercial Human Space Flight operations concept determines that these processes and functions will be part of the service provided by commercial human spaceflight providers. However, the technical standards for what constitutes effective and safe mission planning, crew training, and mission execution (mission control) have not been codified in any agency level documentation. The development and publication of these standards will be a time critical process in the government acquisition of these services. This constitutes significant forward work for the agency as we move toward commercial human space flight acquisition.

### **NASA Review Team Approach**

NASA review teams will be defined for each commercial crew contract or space act agreement. They will be composed primarily of members from the overall Program insight/oversight team and can engage insight members from other commercial crew projects. Specifically, the review team will be composed of the program leadership team, the NASA sustaining insight team from the project and augmented with the temporal support team and other independent experts from other commercial crew projects, NASA, FAA or industry, as appropriate. This provides an adequate level of independence to meet the NASA governance. Their review scope is limited to supporting these major reviews as compared to the more continuous, Standing Review Board model that is being utilized for NASA's current Human Spaceflight missions. This team will review the project's technical, cost, and schedule at key decision points, in-line with the processes outlined in NPRs 7120.5 and 7123.1. Their output products will be key findings, concerns, specific actions and program/project recommendations.

### **Agreement Imperatives**

It is imperative that any agreement with commercial human spaceflight providers be structured to enable a badge-less "in-reach" by the NASA insight team. It is imperative that the government have access to all technical details of the design, design environments, testing plans and results, operational data, and problem resolution functions of the commercial provider. NASA will simply not be able to make an evaluation of the safety of the operation without complete access to all technical meetings, flight data, test data, design data. This must be available. However, the reporting requirements on the vendor are completely tailorable. In other words, the NASA insight team can develop their own reports, summaries, and conclusions without prescribing a particular data reporting requirement on the provider, as long as they have full access to all technical data and meetings.

Additionally, the Launch Services Program has found it imperative to have a contractual mechanism to "buy a test" from the supplier. If the commercial vendor does not feel a test is warranted but NASA requires it for safety approval, NASA should be able to pay for the test under discussion at reasonable rates. The same holds true for specific analyses.

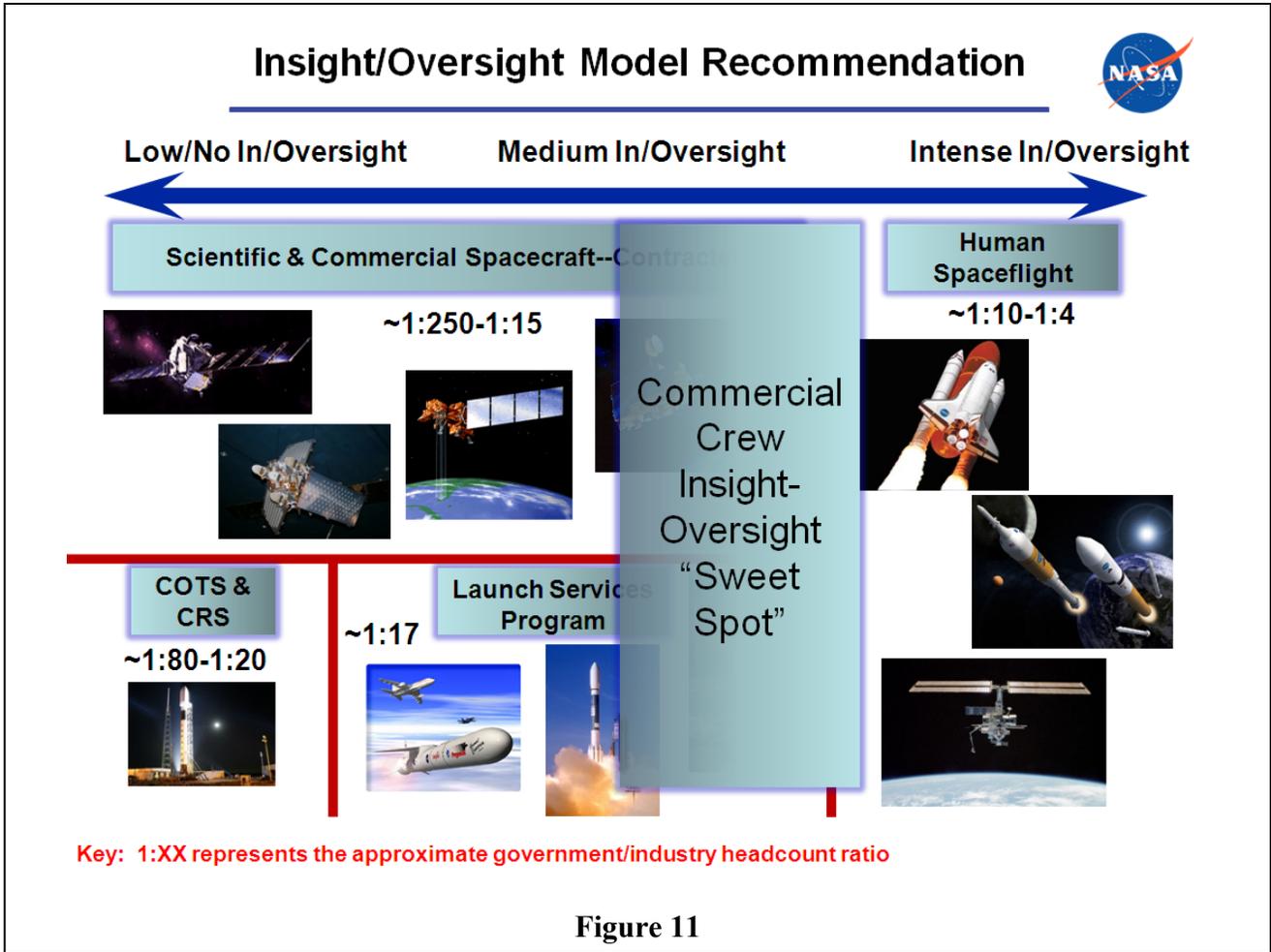
And the agreement should be structured with strong financial incentives which shift mission success to the contract as an accountable deliverable. While government insight/oversight has proven itself to improve vehicle reliability and safety, it should not in any way diminish the vendor's accountability for safety and mission reliability.

### **Commercial Crew Insight/Oversight Recommendation**

As stated previously, this paper proposes a change in the way government and commercial providers interact for human spaceflight missions. The recommended insight/oversight "sweet spot" is shown in Figure 11. This proposal recommends a stronger reliance on the contractor to develop a safe, reliable vehicle, in place of continuous government oversight, used on previous human spaceflight systems. The government team, in this proposal, will transform from their traditional human spaceflight role as continuous oversight "controllers" to become insight "influencers" with judicious, discrete oversight control decision making during the project lifecycle. It proposes a strategic insight/oversight model more in-line with high-valued Launch Vehicles and complex robotic spacecraft. And in-line with robotic spacecraft that provide data that can result in life-or-death decisions for humans on Earth (weather, conflicts, security). And it is in-line with the lower end of the human spaceflight insight/oversight spectrum.

It should be noted that during design, development, and testing prior to first flight certification, more personnel will be required as compared to sustaining operations after a number of successful flights, where fewer personnel will be required. This will move the insight/oversight to the left of the insight/oversight spectrum as sustaining operations matures.

To successfully implement this insight/oversight model, government interfaces with the Contractor (number of engineers allowed to interface with the Contractor), deliverables (DRDs) and requirements need to be tightly (ruthlessly) controlled by the projects and the program. Allowing any of these to be any larger than they have to be or allowing any of these to creep over time results in non-value added cost and schedule increases.



### Summary

This paper has examined the effect of NASA’s safety, reliability, and mission assurance role in the commercial spaceflight service market. It explored and recommended a model for government insight and oversight of low Earth orbit commercial crew systems development and transportation. And it provides recommendations for the right balance of civil servant workforce insight/oversight that will contribute to the safe flight and safe return of NASA crew members on commercial contract vehicles.

Clearly, the recommendations proposed herein represent a culture shift in the way NASA has built and flown its previous human spaceflight vehicles. The government team will need to transform from their traditional role as “controllers” to become “influencers” with judicious, discrete control opportunities. As with any culture change, outstanding, effective culture change leadership is needed within the commercial crew leadership team to move the agency on the right course. And a “can-do” cadre of engineering talent is needed that can simultaneously embrace the importance and criticality of safe, reliable flight and that are willing to adopt the insight/oversight changes necessary to accomplish this in a commercial crew environment. It is also essential for agency senior leadership to invest sufficient time—early and often—to guide

and mentor the NASA commercial crew teams if we are to be successful in this culture change endeavor. As with any culture change, there will be substantial inertia to overcome and the senior leadership needs to be actively engaged to ensure that the optimal commercial crew insight/oversight model is employed.

## **Forward Work**

As this insight/oversight model evolves from proposal to implementation, there are several key drivers that will impact the insight/oversight model and impact vehicle reliability and crew safety that need early attention to ensure Commercial Crew programmatic success.

- 1) NASA needs to develop a well defined decision authority with clearly defined roles and responsibilities. This includes the role of ESMD, SOMD, the program, projects and the agency institution in making this successful
- 2) NASA must codify standards for mission design, crew training, and mission operations so that the service provider can learn from the NASA experience and so that the government can evaluate the effectiveness of the provider's services in these critical areas. The codification of these standards has not occurred in the NASA requirements scheme and determination of which technical authority will be responsible for these requirements has not been made.
- 3) The NASA governance model has the potential to be an insight/oversight driver. As recommended herein, the agency needs to tailor NPRs 7120.5, 7123.1 and 8705.2 early in the program formulation. Moreover, the full complement of design, fabrication and test standards, processes and requirements need to be defined and negotiated between the project and the institution.
- 4) The Certification of Flight Readiness (COFR) process is a critical driver. It defines accountability amongst the various parties. It defines the level and timing of government oversight. And CoFR signatories will require more or less insight depending upon how this process is structured. The vendor and agency roles in this process need to be clearly delineated. The implementation team should make this a high priority effort.
- 5) The procurement needs to be structured to enable badge-less government "in-reach" by the insight team and include strong financial incentives which shift mission success to the provider and their suppliers as an accountable deliverable
- 6) It is crucial for the implementation team to identify clear goals, objectives, requirements and vehicle operability (ground and flight operations) constraints early
- 7) Once the vendor is selected, the early identification of risks (cost, schedule, technical, safety) will guide the oversight model FTE requirements and what insight/oversight augments are required to help mitigate these risks.
- 8) Development of compiled list of pre-declared independent analyses to be performed by the insight team and test verifications that will be reviewed by the insight team. This information will be communicated to the potential commercial crew providers at the beginning of the commercial crew partnership.