Readiness Assessment
of the
Glenn Research Center

Office of Program Analysis & Evaluation
and
Exploration Systems Mission Directorate

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Readiness Assessment of the Glenn Research Center

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Executive Summary

This report summarizes the Organizational Readiness (OR) assessment of the Glenn Research Center (GRC), which was chartered and co-sponsored by the Offices of Program Analysis & Evaluation (PA&E) and Exploration Systems Mission Directorate (ESMD). The OR's charter authorized it to answer the following two questions:

1) Assess the overall readiness of the GRC to perform the Liquid Oxygen/Methane (LOx/CH4) propulsion tasks assigned by the ESMD.

2) Recommend actionable measures to improve and strengthen GRC's ability to take on a larger role for future Vision for Space Exploration (VSE) missions.

Key Findings

Readiness for LOx/CH4 Project

GRC was ready and able to meet the objectives specified in the LOx/CH4 Project Plan. The GRC technical and project management workforce assigned to this effort was qualified and displayed a high level of motivation and enthusiasm for its successful accomplishment. The level of project management experience assigned to the leadership of this effort was appropriate.

Readiness for Other Major VSE Projects

- **Senior Leadership**. As NASA turns its focus toward VSE projects, GRC faces a fundamental difficulty due to its lack of a strategy to position itself as a meaningful contributor to the pursuit of the vision. The failure to develop and implement such a strategy led the center to become dependent on the declining aeronautics, microgravity science, and space technology programs for its future health and viability. This failure was due in part to the fact that the majority of its senior management team did not have space flight experience. It therefore neither fully appreciated nor possessed the knowledge to build the skills and rigors necessary for space flight development and management. There was little recognized capability to lead space flight projects at GRC. Except for the efforts of the Deputy Center Director, there had been limited advocacy for new space flight projects on behalf of GRC to HQ and other centers.

- **Organization**. The GRC organizational design was inappropriate for a large space flight system development. The space systems expertise that exists was fragmented among many organizations. There was no senior executive at the Directorate level to serve as the focal point to plan, advocate for, and execute space flight development projects.

- **Workforce**. The GRC workforce was capable and ready for a major VSE project, and included a good base of project managers upon which to build. However, the technical competency at GRC was deteriorating at a fast pace

with civil servant staff losses increasing and support service pool rapidly disappearing. Morale was generally low across the Center, and became more so with the decision to stand down the LOx/CH4 project.

Recommendations

1. **Redesign the GRC organizational structure to consolidate discipline expertise and establish clear lines of communication, responsibility, and authority necessary to perform a major space flight development assignment.**

2. **Recruit and assign experienced space flight systems development personnel to Space Directorate head and key Division Chief positions.**

3. **Commit to the assignment of significant space flight project work to GRC.**

4. **Depending on the project(s) assigned to GRC, recruit and assign Project Managers with experience in the development of relevant space flight systems.**

5. **Establish and implement an integrated Human Capital Management Plan that enhances programmatic and technical capability within the Space Directorate.**

6. **Develop and implement a plan to achieve compatibility in systems, tools, and processes between GRC and its partner centers in executing the space flight project assignments. This compatibility should be pursued in the area of engineering design and analysis, and project and business management.**

For GRC to fit within the Administrator's vision of ten healthy centers, it needs to be assigned a major VSE role. The degree to which any project assignments can improve GRC's institutional health depends heavily on their nature and timing. A decision on a new space flight project assignment to GRC should be made quickly, followed by a Mid-Term Review (notionally June 2006) of GRC's progress toward addressing its shortcomings. This review would provide Agency leadership an opportunity to take any necessary corrective action.

1. Introduction on Organizational Readiness Assessment

The Organizational Readiness (OR) assessment is a new HQ function performed within the Office of Program Analysis and Evaluation (PA&E). The OR assessment focuses on evaluating the capabilities and preparedness of a NASA organization to perform its assigned missions, along with the potential risk factors and consequences associated with the mission being executed by the subject organization. A project, program, office, or Center can be the subject of an OR assessment.

The major difference between an OR assessment and other types of assessments and reviews, such as the reviews prescribed in the NPR 7120.5C, is that the intention of an OR assessment is to help rather than to discipline; it offers proactive prevention rather than reactive correction.

The OR assessment does more than just identify impediments, risk factors, and consequences; it works with the candidate organization to (1) propose measures to mitigate the risks and remove impediments, (2) identify necessary assistance to help strengthen the candidate organization's overall capabilities and readiness, and (3) provide feedback and recommendations to senior Agency leaders to support the candidate organization and enhance its mission success probabilities. OR assessments promote a stronger Agency with ten healthy centers.

This report summarizes the OR assessment of the Glenn Research Center (GRC). It is one of the pilot OR assessments initiated by PA&E.

2. GRC Readiness Assessment

2.1 Objectives

This GRC Readiness Assessment was chartered and co-sponsored by the Offices of PA&E and Exploration Systems Mission Directorate (ESMD) to answer the following two readiness questions:

I. Assess the overall readiness of the GRC to perform the Liquid Oxygen/Methane (LOx/CH4) propulsion tasks assigned by ESMD.
   a. Identify strengths and weaknesses (potential and/or perceived) regarding GRC's ability to execute human space flight projects that can be identified by this ESMD assignment.
   b. Identify the risk factors associated with GRC's areas of weakness and their likely impact on the Crew Exploration Vehicle (CEV) project and the U.S. Vision for Space Exploration (VSE).

II. Recommend actionable measures to improve and strengthen GRC's ability to take on a larger role for future VSE missions.

a. Recommend strategies to mitigate risk, based on the readiness assessment of GRC to perform current LOx/CH4 propulsion assignments.
b. Identify internal and external impediments to be removed.
c. Recommend critical assistance needed at GRC.

The original Terms of Reference (TOR) for this GRC Readiness Assessment is included in **Appendix A** of this report.

2.2 Background

In the process of distributing VSE project assignments among NASA centers, the Agency strives not only to ensure mission success and safety, but also to leverage the existing skill base at the various centers to rebuild and rebalance NASA engineering competency.

Based on the Exploration Systems Architecture Study (ESAS), the CEV consists of a Command Module (CM), a Service Module (SM), and a Launch Abort System (LAS). The ESAS has also provided top-level requirements for the CEV to provide crew and cargo transport to ISS and to reduce the gap between Shuttle retirement and the initial operating capabilities (IOC) of the CEV.

The ESMD asked GRC to participate and play a major role in the Design, Development, Test & Evaluation (DDT&E) of the CEV-SM LOx/CH4 propulsion by (1) performing advanced technology development prior to the Preliminary Design Review (PDR), and (2) supporting the role of the government for design penetration and insight with the CEV Prime Contractor, with an emphasis on LOx/CH4 propulsion after PDR. Later on, ESMD decided to stand down the LOx/CH4 project during the course of this readiness assessment. The decision to stand down the project was based on technical considerations, and was independent of this assessment. (See Section 3.1 for details.)

2.3 Team Membership

The GRC Readiness Assessment Team (hereafter referred as the Team) included the following members:

- Dr. J.C. Duh was the lead of this GRC Readiness Assessment. He currently serves as the Senior Advisor for Organizational Readiness in the Office of PA&E, NASA Headquarters (HQ).
- Mr. Dennis Dillman was the Deputy Lead for this assessment effort. He currently serves as the NASA Engineering Safety Center (NESC) Chief Engineer for NASA HQ.
- Dr. Ed Hoffman represented the Office of Chief Engineer (OCE) on the Team. He serves as the Director of NASA Academy of Program, Project and

Engineering Leadership and the acting Director of Program Integration in the OCE, NASA HQ.

- Mr. Robert Jankovsky was the GRC representative on the Team. He serves as the Chief of the GRC Electric Propulsion (On-Board Propulsion) Branch, and the Warrant Holder for Electric Propulsion.
- Mr. John Kennedy represented the CEV Project Office on the Team. He is the JSC Energy Systems Division Chief Engineer for Exploration.
- Mr. Larry Ross was a senior consultant to this assessment effort. He is a veteran NASA engineer, project manager, and senior executive with 32 years of experience at GRC, retired as the Center Director of the then Lewis Research Center.
- Mr. Nantel Suzuki represented the ESMD on the Team. He serves as a CEV Program Executive in the ESMD Constellation Systems Division, NASA HQ.
- Mr. Jim Wetherbee was a senior consultant to this assessment effort. He brought extensive management and human space flight experience to this assessment effort. He currently serves as the Vice President for Safety in the Titan Group of the L-3 Communications Corporation.

More detailed biographies of the team members are included in **Appendix B**.

2.4 Assessment Areas and Activities

In assessing the readiness of GRC (1) to perform the LOx/CH4 propulsion technology development, and (2) to assume a more important role for future VSE missions, the Team examined the following areas for data, information, and insight:

- Workforce competency and capabilities
- Program/project management systems, processes, and expertise
- Past project and technical performance
- Infrastructure/facility support and planning
- Center management commitment and strategies
- Collaboration and communication with stakeholders, partners, and customers

The Team received several presentations at the assessment kick off meetings held on November 15-17, 2005 at NASA HQ:

- The CEV Project Office (located at JSC) presented the CEV project management plan and organization, and roles and responsibilities of the various centers in the CEV project.
- GRC presented an overview of its institutional capabilities, organization and management; a current status and trend on its workforce and budget; its space heritage and recent projects; and a self-assessment of the Center and its challenges.
- The GRC LOx/CH4 project team presented the project scope; the perceived technical, schedule, and cost risks; and the current status of the project.
- Results from a recent GRC-sponsored Independent Capability Review (August 2005) were also presented.

The Team then conducted the following site visits:

- CEV Project Office on November 21, 2005,
- GRC on November 30 – December 2, 2005,
- MSFC on December 15 – 16, 2005,
- ESMD on January 5, 2006, and
- JSC on January 6, 2006.

During these visits, the Team interviewed more than 60 people, including all levels of center management, project managers, and technical experts at GRC; its partner centers; and its customers. The Team also toured GRC facilities and labs that support space flight missions, including the Rocket Lab, the Electric Propulsion Lab, etc., as well as the Plum Brook facilities, including the Space Power Facility, the Spacecraft Propulsion Research Facility, the cryogenic lab, and others physical plant resources.

The Team also gathered quantitative data on the space project experience (human space flight, robotic space flight, advanced Research &Technology, and launch vehicles) and skill base of GRC workforce. Detailed GRC data are included in Appendix C.

3. Observations

Per the charter for this OR assessment, the Team performed two reviews. Section 3.1 assesses the readiness of GRC to perform the LOx/CH4 Propulsion Advanced Technology Development (ATD) previously assigned to it. Section 3.2 assesses the readiness of GRC to take a more active role in supporting VSE projects.

3.1 Readiness for LOx/CH4 Advanced Technology Development

During the course of (and independent of) this assessment, ESMD and the Constellation Program Office decided to stand down the CEV Propulsion Advanced Development Project and drop ESAS-derived requirements that the propulsion systems for the CEV and the LSAM ascent stage employ LOx/CH4 propellants. Nevertheless, this assessment included observations regarding the readiness of GRC for the project, which are reported as follows in accordance with the terms of reference.

3.1.1 Technical Capability

The objective of the CEV Propulsion Advanced Development Project was to reduce the risks associated with the development of a cryogenic LOx/CH4 propulsion system and to deliver component and system design data at the CEV Preliminary Design Review for use by the CEV prime contractor as a basis for subsequent development and production. System components included the following: main engine, reaction control engine,

propellant management subsystem (including cryogenic zero-g mass gauging, liquid acquisition devices, propellant tank thermal and pressure control devices, isolation valves, and feed systems), and a helium pressurization subsystem.

GRC led an inter-center team including JSC and MSFC, and was responsible for overall project management; system design, engineering, and integration; and propellant management subsystem design. (See Fig 1.)

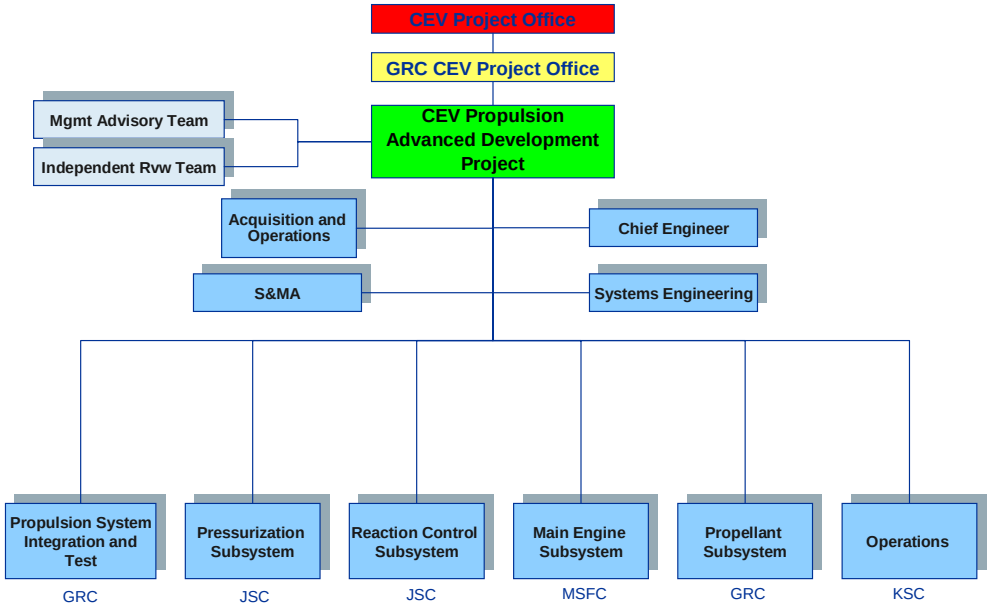

Fig 1 GRC LOx/CH4 Project Office

GRC assigned a high priority to this project, as evidenced by direct and visible support from center leadership, including the marshalling of center personnel and appropriate facilities. The technical staff on this project possessed the appropriate background in a variety of areas and was well qualified to execute this project. Project stakeholders and team members at JSC and MSFC shared this observation. Areas of expertise represented on the GRC LOx/CH4 project included: rocket propulsion systems integration, systems engineering and analysis, low-g cryogenic fluid management, combustion device and injector systems development, and propellant loading operations. Individuals on the LOx/CH4 project obtained their experience from projects such as: the Space Shuttle, ISS, TDRSS, TRMM, SLI, NGLT, X-33, RL-10, and Delta-III. Additionally, some project team members had experience supporting the CEV-SM design activity, which had incorporated propulsion system options featuring either LOx/CH4 or hypergolic propellants.

The technical team was highly motivated and enthusiastic about the project. The team's high morale represented a bright spot in the current GRC environment. The working

relationships between project personnel at GRC and their counterparts at JSC and MSFC were good at the technical working level. A high degree of respect had developed among working groups at various centers. Interfaces appeared to be very open, and there was confidence that technical issues could be raised and resolved collaboratively.

Several GRC test facilities were to be utilized for this project, including the Small Multipurpose Research Facility (SMiRF) and the Cryogenic Components Lab that support cryogenic fluid management testing; as well as the GRC Rocket Lab. In the case of the Plum Brook B-2 facility, the phasing plan for the project's budget required integrated thermal testing to be postponed from an originally desired date in FY07 to a date in FY08 after the PDR. Nevertheless, the Team determined that GRC facilities and their planned funding were appropriate to achieve operational status.

3.1.2 Project Management

GRC had good project management capacity for the LOx/CH4 Propulsion ATD project. Project managers had proper space flight project management experience, and the organizations that provided project support (e.g. Safety and Mission Assurance (S&MA), Procurement) were capable. Project management personnel found ways to work around deficiencies in the GRC organization and senior management. For example, the LOx/CH4 Project Manager had direct communication with the center's Deputy Director.

The multi-center project team was well organized and well managed. The current project management team was committed to establishing trusting and responsive relationships with both CEV Project Office and other centers supporting this project. The LOx/CH4 Propulsion project manager and team successfully worked to improve relations with the CEV Project Office after inheriting serious start-up issues. The project team was gaining familiarity with and adjusting to the processes, culture, and norms of the Human Space Flight program and making positive progress.

3.1.3 Challenges

There were significant technical, funding, schedule, organizational, and management challenges in the LOx/CH4 activity.

From a technical, cost, and schedule perspective, this activity had significant challenges associated with bringing a relatively low technology-readiness-level propulsion system to the development level necessary to support CEV block-1 vehicle needs. The GRC project team was committed to the deliverables specified in the project plan, and there were high probabilities they would have achieved these objectives. However, the deliverables of this project plan (which have been defined based on the funding and development profile from the ESAS activity) would not have matched either the ESAS expectations, or the program needs for risk reduction and technical data necessary to support critical design decision-making in the PDR time frame. Although there was little issue with the ability

to overcome the technical challenges associated with LOx/CH4, given sufficient time and development resources, the program timeline and resources for this activity did not align with those necessary to demonstrate an acceptable technology readiness level for a block-1 vehicle. It was therefore highly unlikely that this technology and systems development would have been mature enough to support the block-1 vehicle needs. Comparisons to previous historical engine/propellant development timelines also supported this conclusion.

This project was very effective in dealing with the broader GRC organizational and management challenges noted elsewhere in this report by implementing a direct reporting chain to the Deputy Center Director. The project management team at the time of this assessment had successfully mitigated initial start-up challenges and issues through attention to communication, both internal and external to GRC.

3.2 Readiness for Major Exploration Projects

The Team assessed the readiness of GRC to take on a more active role in supporting VSE projects.

3.2.1 Senior Leadership/Management

As NASA turns its focus toward VSE projects, GRC faces a fundamental difficulty due to its lack of a strategy to position itself as a meaningful contributor to the pursuit of the vision. The failure to develop and implement such a strategy had led the center to become dependent on the declining aeronautics, microgravity science and space technology programs for its future health and viability. This failure was due in part to the fact that the majority of its senior management team did not have space flight experience. It therefore neither fully appreciated nor possessed the knowledge to build the skills and rigors necessary for space flight development and management. There was little recognized capability at the senior executive level to lead space flight projects at GRC. Except for the efforts of the Deputy Center Director, there had been limited advocacy for new space flight projects on behalf of GRC to HQ and other centers.

The attitude of many senior managers toward new business development was passive, fostering the impression that they were not assertive enough to acquire new work. Management perpetuated the sense that GRC should be given work, rather than having to earn it. The primary interest of the senior managers at GRC was in aero research, and their perceived bias was toward funding aero facilities rather than space facilities. As such, their priorities did not align well with those of the Agency or VSE. Due to senior managers' limited backgrounds in space flight project management and limited reputations in the space systems development community, they were ineffective at strategizing about and implementing new VSE projects. The Team was informed that a new strategy was completed, but was not released pending the arrival of the new Center Director. The strategy was therefore not shared with the Assessment Team.

The lack of ability to develop long-term strategies was compounded by a failure to communicate effectively with the workforce about the current strategic landscape. The message that some managers imparted was: "Keep our heads down and we will get back to doing research again." Some workers also perceived that senior management was reluctant to be held accountable for new high-profile work.

Consequently, the Team found widespread discontent with senior managers. The workforce saw a lack of conviction and commitment of some senior managers to the VSE, and believed that management could not lead the center into the mainstream of the space exploration business.

Senior management did not appear to have a clear grasp of the workforce development challenges that it faced. It lacked an understanding and appreciation of the needs and requirements to cultivate and strengthen the rigor of engineering and project management skills. Key engineering managers did not understand the needs, capabilities and skills of other centers, which limited their ability to envision GRC's role within the broader context of NASA's technical community.

Finally, the Team found examples in which senior managers were unwilling to make tough decisions or prioritize work. In these instances, they exhibited a tendency to manage by vote rather than leading their workforce, and they were characterized as being patient, forgiving, averse to conflict, and oriented toward appeasement.

3.2.2 Organizational Design

The GRC organizational structure was not conducive to the conduct of space development activities. The most serious shortcoming in this regard was the absence of a Directorate-level organization for space, which should be responsible for setting and executing operational strategies. This led to a lack of focus for GRC space development work, resulting in impaired advocacy both within and outside of GRC. It was also a serious handicap in ensuring effective leadership and oversight in the execution of such work.

A second defect was the fragmentation of the expertise required to conduct space flight projects across multiple center organizations. For example, the recent SM Capture Team consisted of twenty-five individuals representing four different directorates and eleven branches. This unwieldy matrix placed an unnecessary and inefficient coordination and communication burden on the Project Manager. Another example of counterproductive fragmentation was the placement of the flight software team, an engineering discipline, in the office of the Chief Information Officer. An unfocused space development workforce can create an impediment in the effort to install and maintain the standards and rigor critical to space development projects.

A third defect was the grouping of aero R&T activities with space development efforts in the same organization. Due to the very different nature and focus of the two types of activities, it was challenging to standardize processes and requirements across such an organization, making it difficult to cultivate the necessary engineering and management rigors required by the space development projects.

3.2.3 Project Management

GRC's readiness to assume project management responsibility on major exploration projects was mixed. The center did not have a team of senior project managers with experience in major space projects. At the same time, there was a pocket of excellence within the microgravity science program, as well as a residual culture of success from previous space flight projects.

GRC's experience with the microgravity science program has nurtured a cadre of high quality project managers. Some personnel external to GRC referred to GRC's capability in this area as the best kept secret outside of the micro-G community. Although most of these projects were smaller-scale payloads, the opportunity for a project manager to manage through the complete project life cycle (DDT&E, to operations, to de-commission) and to manage by rigorous flight project management practices – including human rating – was a valuable one. These project managers can benefit and grow under proper mentorship of more experienced senior project managers.

GRC had an impeccable record on the past performance of space projects. Given the lack of work in this area in recent years, though, space flight project management culture and practices need to be cultivated and focused at GRC. Project managers at GRC were willing to work with their counterparts at other centers and adapt to other ways of accomplishing tasks. Building this culture and heritage will require more than high personal qualities and creativity. It will require leadership by champions within a senior management team that has recognized strength in space flight projects.

3.2.4 Workforce Technical Capability

At the time of this assessment, GRC had a highly trained and technically capable workforce that was ready to be deployed on meaningful space exploration projects. There were approximately 400 civil servants and 100 support service contractors with relevant skills and experience available to support space exploration projects at GRC. Most of their space project capability and experience came from microgravity science payload projects (most recent), Space Station power systems projects, Advanced Communications Technology Satellite projects, and launch vehicles projects (more distant). Expertise in Expendable Launch Vehicle-type development existed at GRC, but it was not as deep. Due to attrition and the lack of major space hardware development projects at GRC in recent years, GRC's technical base in space systems development was not as extensive or diverse as at other space flight centers.

The GRC technical staff appeared committed to the VSE and determined to engage in VSE projects. The Team found that the technical staff had attempted numerous "bottom-up" space project advocacy activities, showing great initiative and commitment.

Technical competency at GRC was deteriorating at a fast pace. People were leaving due to the lack of new work, the looming reduction-in-force (RIF), and the unclear or nonexistent GRC strategy to advocate for more exploration projects. As an example, the flight software area lost 30% of its support service contractors in the first 8 months of 2005, and 50% for the full year. Workforce morale was generally low across the center.

3.2.5 Facilities

GRC had some unique facilities and test capabilities that would be unrealistic to re-develop in the current budget environment. These facilities and test capabilities represented irreplaceable Agency assets. Though the Exploration-relevant facilities were available and ready to support Exploration projects (and may require relatively minor upgrades), other GRC facilities and basic infrastructure were seriously under-funded. Some infrastructure was in an unhealthy state.

The Plum Brook facilities were well managed under the fiscal constraints. The managers supported their workers and encouraged creative problem-solving skills. Together, they kept their facilities at a high state of readiness, and their visible and vibrant safety program protected the people and their hardware. The Plum Brook team demonstrated a sense of commitment to the Agency and their customers to keep the test facilities working. Regardless of the disposition of Plum Brook facilities, the practices employed by the managers were outstanding, and their methods should be shared to benefit other groups in the Agency.

3.2.6 Communications outside GRC

Although the previous Center Director had assigned various senior managers as the points of contact to reach out to other centers, the Team found little evidence during subsequent interviews at other centers that the outreach effort was successful. Other observations include:

- Few senior managers (Directorate-level and above) at other centers reported that they had any contact with their peers at GRC.
- Senior managers at GRC had differing opinions about who at GRC was reaching out to other centers to solicit work for GRC.
- There appeared to be no guideline or impetus for GRC senior managers to contact their peers at other centers to have "face time" and to solicit work.

3.2.7 Other

The Team noted several additional significant items worth highlighting that did not readily fit in any of the other major observation sections of this report.

1. Many believed the image of GRC as a "Research Center" had hurt its effort to get new business in space exploration.

   There was a widespread perception outside of GRC that the center primarily does research, particularly aero research, rather than space flight project activities. The reality is that GRC has a rich history in both space and aeronautics research, and it has a subset of individuals who have recent experience supporting space flight projects such as ISS power systems and microgravity projects. Recognition of this capability resided primarily in the organizations supported by GRC in these areas. This core of individuals with recent spaceflight projects experience, numbered approximately 400 civil servants.

2. The HQ-directed "work package transfer" effort had not produced significant beneficial results for GRC.

   The recent "work package transfer" activity undertaken by the Agency in an attempt to move work to the research centers has failed to provide significant relief to the current GRC workforce challenges. The nature of the work approved to date had resulted in fractions of FTE assigned to support activities led by other centers, rather than a set of tasks and products with clear lines of responsibility. These types of assignments do not provide for the development of long-term competencies necessary to maintain a healthy center.

3. GRC personnel exhibited a high-level of distrust of other centers, including HQ.

   A persistent theme among GRC management and workforce was that other centers and HQ were "out to get them." This feeling of distrust was indicated with negative statements directed at centers that had rewarding work. The Team believes this behavior is systemic at struggling centers, and is not an indication of a weakness or low state of readiness at GRC. Rather, this pessimistic outlook was a symptom of the lack of communication from the leaders of GRC, coupled with a history of losing work.

   It was interesting to note that when individual relationships were mentioned, the workforce espoused feelings of respect and trust for their colleagues at other centers. The workers were able to maintain a healthy rapport with people they knew personally. This was the expected response from the highly dedicated engineers employed by NASA.

4. People were not afraid to voice their opinions -- a research attribute.

A key attribute of GRC, which has been attributed to the center's rich research historical culture, was unconstrained input on technical issues and concerns. This technical input was unbiased by program or project concerns and provided a valuable independent perspective. This attribute was recognized by personnel both at GRC and other centers.

4. Conclusions

4.1 Readiness for LOx/CH4 Advanced Development

At the beginning of this assessment, GRC had been assigned the lead role for advancing the LOx/CH4 propulsion technology as the baseline option for the CEV SM, with the understanding that an informed choice for CEV propulsion would be made at PDR in 2007. However, the requirement that the SM propulsion system use LOx/CH4 propellants has since been removed, and the CEV Propulsion Advanced Development Project, as originally conceived, is no longer needed to support decisions at the CEV PDR. Since there may be potential for some of the project's personnel and scope to be re-directed into a longer-term technology effort for ESMD, the Team hoped that the portion of this assessment devoted specifically to the LOx/CH4 project will prove valuable. In this context, conclusions regarding GRC readiness for LOx/CH4 advanced development are described below.

The workforce at GRC was ready and was able to meet the objectives specified in the LOx/CH4 Project Plan. The GRC workforce assigned to this effort was qualified and displayed a high level of motivation and enthusiasm for its successful accomplishment. The level of project management experience assigned to the leadership of this effort was appropriate. In particular, the Project Managers had excellent technical and managerial backgrounds and had earned great respect from the team both at GRC and at the other contributing centers. One feature of the GRC approach was the adoption of an ad hoc solution to deficiencies in the GRC organizational design – a direct communication path between the Project Manager and the Deputy Director that bypassed middle management.

The managers of the LOx/CH4 project at GRC were ready and already making good technical and project management progress when the CEV Project announced its decision to remove requirements for LOx/CH4 propellants. Evidence of project management progress could be found in the attention being paid to forming a viable working relationship with the partner centers, MSFC and JSC.

4.2 Readiness for Other Major VSE Projects

The GRC technical workforce is ready for a major VSE project. However, there are serious readiness issues exist that must be overcome by bringing in new senior leaders

who possess strong space flight project experience and by revamping the organizational structure.

A solid cross-section of journeymen and lead engineers with significant and applicable space systems development experience exists within the present GRC workforce. They are ready and eager to become part of a priority Agency program. While some workforce areas needed strengthening, such as the number of senior experienced project managers, GRC had the core talents that can be built upon to undertake major VSE projects.

While the workforce may be ready and eager, there are shortcomings in GRC senior management and the basic GRC organizational design. The GRC senior executives (down to Division level) did not, in general, have the strong space project leadership credentials necessary for successfully managing a major space systems development. Nor had the senior managers at GRC been effective in addressing the concerns of the workforce and the future of the center in recent years. Consequently, the working-level staff had low regard for the leadership capabilities at GRC and low confidence that senior management could lead the center into the mainstream of the space exploration business. As the civil servant staff continued to downsize and the support service talent pool rapidly shrank, workforce morale was generally low across the center, and became more so with the decision to stand down the LOx/CH4 project.

While it is recognized that a Mission Directorate would manage such a development through the Program and Project Managers it appoints, a successful project outcome is dependent on the performance of center resources. A qualified center senior executive staff is critical to the delivery of technically excellent services to the project. Senior center leadership is also critical to ensuring that the center resources remain viable and grow in capability as needs change and new technologies emerge. Furthermore, without experienced leaders, the center cannot meet the challenge of crafting and implementing strategies to position it for future opportunities.

In addition, the GRC organizational design is inappropriate for a large space flight system development. The space systems expertise that exists is fragmented among many organizations, and there is no senior executive at the Directorate level to serve as the focal point to plan, advocate and execute space flight development projects.

5. Recommendations

To achieve a level of readiness that is sufficient to accept an assignment of major work to support the VSE, the leaders at GRC must take action to address shortcomings in staffing of senior management and correct an organizational design that does not support sound space flight development practices. The details of these actions will depend on what work is assigned. Therefore, the first step of the necessary actions is to identify a proposed assignment, and this decision should be made as soon as practical because GRC is not a healthy center and becomes markedly less so as time passes. This new project

assignment to GRC should be provisional so the Agency can retain the option to take corrective actions if GRC does not overcome its deficiencies in the required period of time. Assuming that GRC will undertake VSE project work in the near-term, the Team recommends a Mid-Term Review, 3-4 months after the announcement of assignments (notionally in June 2006) to assess GRC's progress in implementing the actions. Should the senior leaders in the Agency decide to assign work to GRC in a later phase of the VSE program, a less demanding schedule for accomplishing these recommendations could be required.

5.1 Organization

Recommendation 1: Redesign the GRC organizational structure to consolidate discipline expertise and establish clear lines of communication, responsibility, and authority necessary to perform a major space flight development assignment.

The GRC Center Director should develop a plan for the establishment of a space organization (and the consequent revisions to the other line organizations), which should be approved by the NASA Associate Administrator. Development of this plan will require substantial collaboration with the individual chosen to lead the Space Directorate (see Recommendation 2), as well as the individuals in other Directorate-level positions. Implementation should take place as soon as possible, with the expectation that substantial progress towards reorganization will be evident by the Mid-Term Review (notionally in June 2006).

The organizational structure of GRC is a major impediment to successful implementation of a space flight development project. A space-focused organization at the Directorate Level is necessary. This organization should be the line organization responsible for all space-related projects (including R&T), and should include all of the engineering expertise and functions, tools, processes, and procedures unique to the performance of space systems R&T and development activities. One exception to this consolidation is the Safety and Mission Assurance organization, which should remain separate and have its own reporting chain to the Center Director.

5.2 Organizational Leadership

Recommendation 2: Recruit and assign experienced space flight systems development personnel to Space Directorate head and key Division Chief positions.

The Center Director should, in consultation with Agency executives, recruit a new Space Director from a list of qualified NASA, DoD, and industry candidates as soon as possible. This will serve the goal of infusing much-needed space flight experience into senior management. The new Space Director should possess the following qualities, skills, and competencies:

- A demonstrated track record in major space flight system development.
- Recognition as a leader capable of invigorating the workforce.
- A reputation for setting high and demanding technical and programmatic standards for achieving project success.
- An extensive network of contacts within the space flight development community.
- The vision to champion the development of space flight capabilities and culture at GRC.

It is expected that identification and recruitment of a senior, experienced executive, with the caliber needed for the Space Director position, will require the active support of senior Agency management.

Following assignment of a Space Director, GRC should begin to establish a Space Directorate (Recommendation 1). As the design of the new organization takes shape, and with a clear understanding of the specific characteristics of the Space System development role to be addressed, the Center Director, with input from the new Space Directorate head, should identify the key positions below the Space Director level for which there are no qualified GRC candidates. (See Recommendations 4 and 5.) These positions should be filled through a targeted recruitment effort designed to infuse the necessary level of experience. Again, this effort will require the support of senior leadership in the Agency.

5.3 Assignment of Work

Recommendation 3: Commit to the assignment of significant space flight project work to GRC.

For GRC to fit within the Administrator's vision of ten healthy centers, it needs to be assigned a major VSE role. The degree to which any project assignments can improve GRC's institutional health depends heavily on their nature and timing. GRC is in critical need of a leadership role for a discrete, self-contained, and durable project for the development of hardware in the critical path of VSE. Such a project leadership role will help GRC maintain the basic intellectual and institutional health of the center, allow it to thrive and re-align with the Agency's priorities re-establish its identity, and offer it a much needed opportunity to prove, once again, its capability in managing and developing space systems. The Team agrees with the views expressed by the Systems Engineering and Institutional Transition Team (SEITT) that a healthy center must have responsibility for a major, in-house spaceflight project, combined with clear and enduring roles and responsibilities.

It is therefore strongly recommended that the NASA Administrator provisionally assign a major space flight project to GRC, with the understanding that readiness conditions must be met at the center. The authorization to proceed with new project work should be contingent upon demonstration of significant progress in responding to the

recommendations of this assessment, and upon successful completion of Recommendations 1 and 2 in particular, because major organizational and management changes are required at GRC to maximize the potential for mission success. The assignment should be confirmed based on a Mid-Term Review of GRC readiness (notionally in June 2006).

Feedback from GRC and other centers indicates that the GRC workforce is capable of executing projects among the Agency's near-term strategic investment portfolio, such as Tracking and Data Relay Satellite System (TDRSS), Exploration Communications and Navigation System (ECANS), Little Joe-III, or the CEV Service Module (SM).

Depending on the nature of the assigned work, varying degrees of resource augmentation and infrastructure development (e.g., personnel reassignment and/or exchange, engineering and management tools, teaming arrangements) will be necessary for ensuring mission success and the long-term health of the center. The tools and resources necessary to execute a TDRSS or ECANS project successfully will be significantly different than those required for a human-rated dynamic flight vehicle such as the CEV SM. The additional safety, reliability, operational flexibility, and systems integration demanded by human-rated spacecraft systems results in a more complex engineering development process than is required for non-human systems. As a result, supporting an activity such as CEV SM will require significantly more infrastructure development and resource augmentation than an effort such as TDRSS, which is closer to the GRC experience and heritage.

The timing for commencing a major project at GRC is critical to ensuring the continued health of the center. This health depends not only on the identification of enduring spaceflight responsibilities at GRC in the long-term, but also on specific near-term project assignments that could establish an immediate focus for the center, thereby stemming the observed deterioration of overall technical competency, and assisting efforts to recruit much-needed engineers and managers with space development experience. The assignment of work must also be viewed in terms of its effects on the health of other centers in light of current planning for the Space Shuttle termination and future Space Station utilization. Defining a niche and identity for GRC within NASA is necessary to mitigate competition and conflict between GRC and other centers.

5.4 Project Leadership

<u>Recommendation 4</u>: Depending on the projects assigned to GRC, recruit and assign Project Managers with experience in the development of relevant space flight systems.

The Program Manager should work together with the GRC Center Director and Space Director to recruit Project Managers with experience in the development of relevant space flight systems. Project Managers assigned to space flight projects shall possess:

- Reputations for superior technical and programmatic abilities, and

- Strong leadership skills.

5.5 Workforce Development

<u>Recommendation 5</u>: Establish and implement an integrated Human Capital Management Plan that enhances programmatic and technical capability within the Space Directorate.

The Space Director should appoint a manager to lead a Human Capital Management Process. The Human Capital Management Plan should:

- Include a strategy to identify current workforce strengths and weaknesses (for example, using the NASA/PMI Assessment & Gap Analysis Tool).
- Leverage the existing NASA Project Management and Engineering Competency Framework [Academy Program/Project and Engineering Leadership (APPEL)] that targets Systems Engineering and Project Management as a way to baseline standards of high performance.
- Based on results of the Gap Analysis and Competency Framework, fill vacant positions by:
  - Establishing a training and development strategy for building and maintaining expertise in Project Management and Systems Engineering
    - Emphasis should be placed on experiential (hands-on) learning
    - The Space Directorate should establish training and development requirements through technical experts using the NASA Project Management & Engineering Development Process, and
  - Transferring competencies from other centers
- Ensure a healthy support service contractors base.

Progress shall be presented at the Mid-Term Review (notionally in June 2006).

5.6 Collaboration

<u>Recommendation 6</u>: Develop and implement a plan to achieve compatibility in systems, tools, and processes between GRC and its partner centers in executing the space flight project assignments. This compatibility should be pursued in the area of engineering design and analysis, and project and business management.

There is a need to achieve compatibility among the engineering design, analysis, project and business management systems, tools, and processes to be employed by GRC and partner centers in the execution of the space flight project assignments. Integration among centers requires seamless transfer of information using common tools and processes. The positive results of collaboration between MSFC and JSC – their standardization of tools and practices, as well as development of a common "vocabulary," can serve as an example. The direction taken to develop commonality will likely be dependent on the major projects assigned to the center. Choice of a project

related to human space flight would point to standardization with the tools and practices currently used by JSC and MSFC, while choosing a TDRSS-type project may lead to standardization with tools and practices employed by JPL and/or GSFC. These differences may include: standard analysis tools, materials utilization, boards and reviews, configuration management, traceability, safety reviews, drawing control, fault tolerance approaches, and categorization of design for minimum risk. Depending on the specific nature of the new GRC assignment, the path to readiness for successfully performing the assignment includes the requirement for GRC to:

- Ensure that the full range of technical, business and programmatic management tools and systems are active within the GRC performing organizations (e.g. thermal analysis, configuration management, design tools, project scheduling, cost estimating, contract management, etc.).
- Actively certify and demonstrate that these tools and systems are compatible with the counterpart tools and systems at the partner centers and contractors.

The development of compatible tools and practices must be combined with a commitment to strengthen communications between management at GRC and their counterparts at other centers. Although communication has taken place at the working level, it must be improved at the senior management level at GRC. As a minimum, the requirement for such communication should be included in the performance plans of all GRC senior management. From an Agency perspective, consideration should be given to hosting an annual engineering workshop, with the intention of pulling together practicing engineers and first-line engineering managers in a neutral environment to exchange information and ideas, and improve alignment of engineering tools, methods, and processes.