S5-02

FIGURES OF MERIT FOR AERONAUTICS PROGRAMS

and

ADDITION TO NASA LARC FIRE STATION

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ABSTRACT

This report accounts details of two research projects for the Langley Aerospace Research Summer Scholars (LARSS) program. The first project, with the Office of Mission Assurance, involved subjectively predicting the probable success of two aeronautics programs by means of a tool called a Figure of Merit. The figure of merit bases program success on the quality and reliability of the following factors: parts, complexity of research, quality programs, hazards elimination, and single point failures elimination. The second project, for the Office of Safety and Facilities Assurance, required planning, layouts, and source seeking for an addition to the fire house. Forecasted changes in facility layout necessitate this addition which will serve as housing for the fire fighters.

INTRODUCTION

Langley Aerospace Research Summer Scholars (LARSS) program time was spent in the Office of Safety, Environment, and Mission Assurance (OSEMA). Program managers involved in aeronautics research, space payloads, or facilities planning at any NASA center may contact OSEMA. Once called upon, the office will not partake in any direct research or engineering. Rather, OSEMA assumes the role of a disinterested third party which objectively reviews the quality of the engineering, the parts, and the program itself. Once involved with a program, OSEMA has the power to prevent that program from taking place if it proves potentially dangerous to personnel or equipment. OSEMA believes their services add value to NASA programs by assuring the quality and reliability of the systems and structures involved.

Personal involvement with OSEMA was in the areas of both aeronautics and facilities safety, reliability, and quality assurance. The first half of the program was spent in the Office of Mission Assurance, a subset of OSEMA responsible for the review of aeronautics programs and space payloads. There, the assignment was to survey two of the aeronautics programs OSEMA was asked to oversee in order that a figure of merit be determined. The figure of merit is a subjective method of determining the probable success of a program on the basis of the following five factors: parts, complexity of research, quality programs, hazards elimination, and single point failures elimination. A single point failure is the failure of any one item that will result in the complete destruction of property and/or death. The aforementioned categories are assigned weights, and are then subjectively rated on a scale of 0-4 on the basis of a review of the quality and reliability programs in place. The products of the weights and ratings for each category are then summed. The total score will be between zero and four and is evaluated much like a GPA, with a zero being a likelihood of failure, and four being the likelihood of complete success. It should be mentioned that the figure of merit model inherently assumes that the more complicated a project is, the less likely it is to succeed. Figure 1 shows a schematic of the figure of merit categories, weights, and ratings.

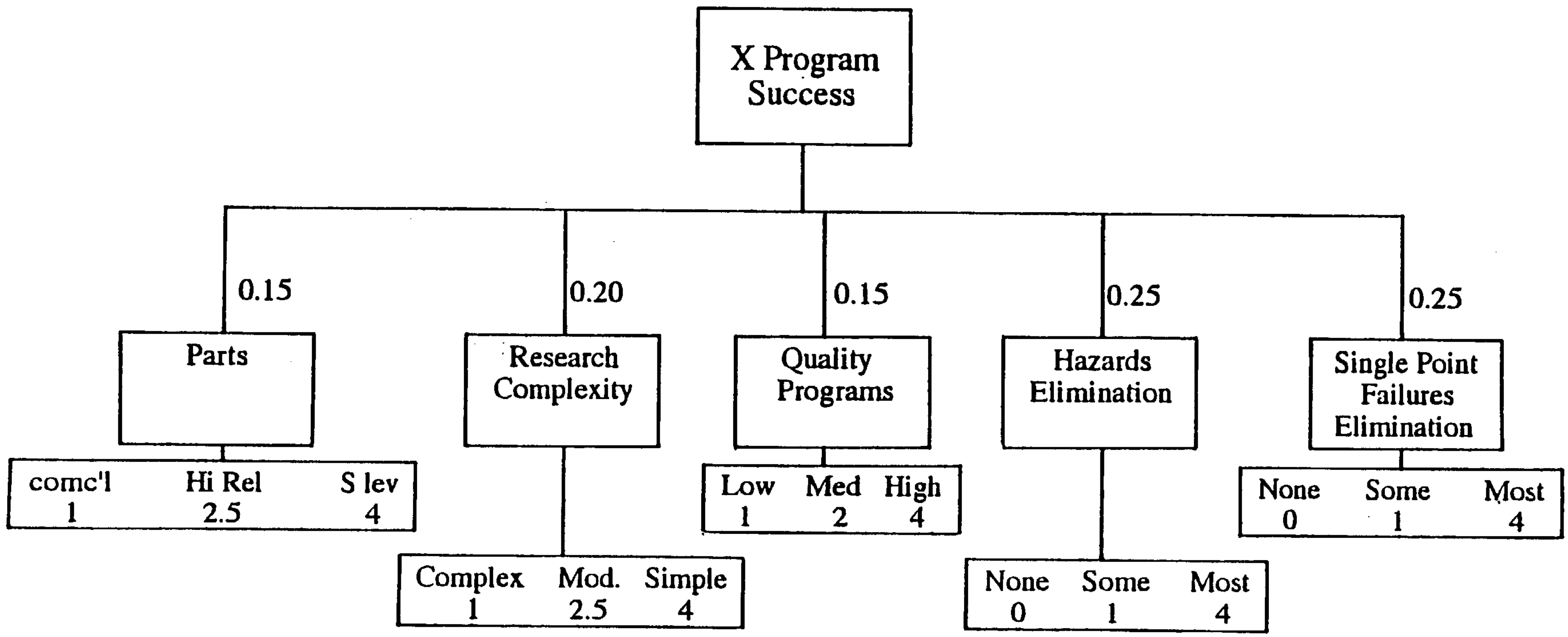
The second half of the summer was spent in the Office of Safety and Facilities Assurance, another sub-area of OSEMA. The project in the facilities area was to research and provide layouts for a prefabricated addition to the fire station. This addition will serve as housing for the fire fighters and will become necessary when the NASA Langley emergency operations center (EOC) comes on-line, for the EOC will be located in the area which currently shelters the fire fighters. This project required research of potential vendors, study of existing NASA facilities and utilities, interface with vendors and NASA personnel, cost estimating, and cost engineering.

AERONAUTICS PROGRAMS

<u>F-16XL LAMINAR FLOW CONTROL</u>:
This experiment, which involves one of two proposed lift control devices for the high speed civil transport, aims to maintain laminar flow over a longer extent of the wing chord than is currently possible. Since friction between the wing and boundary layer air is responsible for the onset of turbulent flow conditions, this project proposes to extend laminar flow by using suction to pull the boundary layer air into the wing.

The apparatus for this experiment includes the F-16XL (ship no.2) which is located at NASA Dryden Flight Research Center in California, a wing glove, and a suction control system. The design, engineering, and assembly of the wing glove and the suction system was subcontracted by Rockwell International to Boeing Commercial Airplane Group and McDonnell Douglas Corporation (MDA), respectively. Rockwell International was involved as the prime integrating contractor and served as a liason between NASA and the contractor team. As such, Rockwell was

Figure of Merit



comc'l - commercial
Hi Rel - high reliability
S lev - space grade

Figure 1

responsible for coordinating interface meetings and providing the performance, schedule, and cost status.

In the most brief and general terms, the glove is a 0.5 inch deep sandwich panel. The outer skins consist of two titanium sheets. The outer skin is perforated with laser drilled holes, the inner sheet is unperforated. A series of aluminum "I" stiffeners run parallel to the leading edge of the true wing and are bonded to the two sheets. These stiffeners provide the core of the panel sandwich. The wing glove attaches to the existing wing by means of a series of inverted channel members which run perpendicular to the leading edge. These ribs break up the suction panel into acceptable planform dimensions and provide a means of attaching the glove to the true wing.

The suction system, which is located between the glove and the true wing, consists of a series of valves and sensors, ducts and couplings, plenum, and an onboard suction system controller which provides automatic management of all flow control valves. The suction system pulls the boundary layer air through the perforations in the glove, ducts it to the suction manifold, and discharges it overboard.

OSEMA'S ROLE:
As mentioned previously, Boeing was responsible for the wing glove. They provided a satisfactory product and delivered it on schedule. MDA, however, requested exemptions and extensions and provided no interim design or engineering information. These circumstances prompted the program manager to call in OSEMA to provide test requirements for the delivered product which would insure hardware function within the limits of the schedule.

MDA delivered the control box on schedule -- overweight and oversize. Additionally, since MDA subcontracted the design and assembly of the box to a model shop with no previous experience in the aerospace industry, OSEMA supposes that the box was not engineered to withstand the dynamic environment of an aircraft. However, this issue cannot be investigated because MDA claims they have no drawings for the box. Further, the box smoked during testing, and the cause of the smoke has not been investigated.

Finally, the presence of the glove on only one wing results in an asymmetric arrangement. The contractors claim this design will not cause adverse handling effects or compromise flight safety at test speeds or in the Mach-altitude corridor which gives access to the test region. This observation is true, but fails to address issues of controllability at landing approach speeds where the rudder loses authority to compensate for the modified planform.

All the above mentioned safety issues must be resolved before OSEMA will allow the experiment to fly.

OV-10 WAKE TURBULENCE:
This program aims to study the dangerous and potentially deadly wakes of aircraft and the atmospheric conditions that surround these occurrences. NASA believes that air traffic may be managed more efficiently once these events are better understood.

The test aircraft is an OV-1O Bronco outfitted with equipment to measure and record the atmospheric conditions surrounding wake vortex events.

OSEMA'S ROLE:
While the scientists and experimenters on this program already had safety programs in place, OSEMA was called in to review their processes. This review included an assessment of the integrity of aircraft modifications, an investigation into the possibility that test equipment located on the wing could induce destructive vibrations, and a critique of their hazards analysis.

GENERAL:
OSEMA's role in any aerospace program is to be present at Airworthiness Safety Review Boards (ASRB's). ASRB's represent a formal occasion to bring up and resolve any outstanding safety issues. If any board member believes that such issues remain, there is a possibility that the experiment will not fly.

FIGURE OF MERIT RESULTS

The Figure of Merit results for the F-16XL Laminar Flow Control program and the OV-10 Wake Turbulence program follow.

Figure of Merit for F-16XL Supersonic Laminar Flow Control Experiment

PARTS:
Parts for the project will be purchased "off the shelf" as well as specially made. Therefore, parts merit a weight near two.

RESEARCH COMPLEXITY:
The project is quite complex in that several contractors must interface ideas as well as equipment. Additionally, this project will require the inception of several original designs as well as the fabrication of those designs. Once the design and construction is complete, a means to collect and analyze test data becomes necessary which further requires the availability of ground and flight support teams. These observations correspond to a weight near 1.

QUALITY PROGRAMS:
The establishing of quality control measures is the responsibility of the individual contractors and subcontractors. Per the memoranda on file and on the basis of past conversations, it is apparent that Boeing's quality control actions were satisfactory, while McDonnell Douglas had no quality control programs whatsoever. When the two come together, quality approaches a medium value of 2.

HAZARDS ELIMINATION:
Neither contractor specifically calls out a hazards elimination program, or a hazards identification program, for that matter. The quality assurance measures that Boeing had in place could infer a reduction in the potential for hazards, but the fact that no specific review programs are mentioned suggests that no such program exists. As for McDonnell Douglas, their lack of quality programs guarantees the lack of a hazards identification or elimination program. These observations warrant a rating of 0.

SINGLE POINT FAILURES ELIMINATION:
No single point failure identification or elimination program is mentioned, and no measures have been taken by either contractor to enact such a program. This state conforms to a rating of 0.

FIGURE OF MERIT:

Parts:	2(0.15)
Research Complexity:	1(0.20)
Quality Programs:	2(0.15)
Hazards Elimination:	0(0.25)
Single Point Failures Elim.:	0(0.25)
	0.8

Shortly after the completion of this review, the contractor team submitted a preliminary hazard analysis. The team's examination identified potential hazards, their severity, causes, and effects. Control measures are also included in each scenario. The presence of this review brings the hazards elimination rating up to a 4.

A single point failures program is still not specifically mentioned. Some critical hazards which could cause loss of life and/or aircraft are included in the hazards analysis. However, the team's historical lack of quality programs leads to a reluctance to give the single point failures elimination program a rating higher than 1. The above factors lead to a revised firgure of merit of 2.05.

Figure of Merit for OV-10 Wake Turbulence Program

PARTS:
This experiment utilizes commercial parts, modified commercial parts, and specially fabricated parts. Commercially available equipment constitutes the majority of the parts requirement with some items necessitating minor modifications. In general, these changes proceeded without event. Likewise, the design and fabrication of specialized parts required limited effort. While most parts were commercially available, part modification added slight complication to the project, and design and fabrication of original ideas further added to the project's complexity. Therefore, the sum of all these factors constitutes a rating of two. This airplane is maintained to FAA standards with TSO'd parts.

COMPLEXITY OF RESEARCH:
The project seeks to address unanswered questions, but utilizes conventional means to achieve that end. The measurement tools, recording instruments, and means of analysis are standard and, with few exceptions, commercially available. Arrangement of these instruments, however, was quite a bit more complicated, requiring rather extensive overhaul and modification of the test aircraft. These alterations occurred according to plan and within the limits of the schedule. Additional difficulty could have arisen with respect to the interface of facilities and research partners. However, most exchanges transpired without incident or delay. While the logistics of this experiment are not simple in nature, the personnel involved made it appear commonplace. Therefore, the complexity of research merits a moderate weight of 2.5.

QUALITY PROGRAMS:
The engineers and designers instilled quality into each step of their programs. The engineers addressed matters of structural integrity and design limitations by testing questionable items. Further, weekly meetings kept all involved parties "up to speed" and addressed various areas of concern. In addition, aviation safety review boards (ASRB's) were scheduled and briefed, and all review board recommendations were carried out. Moreover, QA inspected all modifications to insure safety and integrity. These items demonstrate the presence of an admirable quality program warranting a high rating of four.

HAZARDS ELIMINATION:
Hazard analyses were conducted and documented. The hazard reports identify causes and effects as well as any other relevant information, including an assessment of the probability of occurrence. Further, the reports cite means of control or corrective actions. The analyses are thorough, follow standard NASA guidelines, and serve to eliminate most of the hazards or potential for hazards, entitling the program to a rating of four.

SINGLE POINT FAILURES ELIMINATION:
While a single point failures elimination program is not specifically called out, the hazards analysis covered areas that are considered single point failures. The examination consists of causes and effects, additional pertinent information as well as an evaluation of the probability of occurrence.

The analysis also identifies failure controls or corrective actions allowing the program a rating of four.

FIGURE OF MERIT:	
Parts:	2(0.15)
Research Complexity:	2.5(0.20)
Quality Programs:	4(0.15)
Hazards Elimination:	4(0.25)
Single Point Failures Elim.:	4(0.25)
	3.4

FACILITIES PROJECT

NASA Langley Research Center is currently involved with the development of an emergency operations center. This facility will be located in the area of the fire station which currently houses the fire fighters on duty. Therefore, it will be necessary to provide alternate shelter for the fire fighters when the EOC comes on-line. Due to budget constraints and restrictions on new construction the housing facility must be a prefabricated Butler-type building.

The first step in the project was to establish a minimum and maximum arrangement, and estimate the square footage requirements. The minimum layout would include a bunkroom capable of housing approximately ten men and two women and full bath facilities. Ideally, the structure would include full bath facilities, kitchen facilities, a men's bunkroom, a women's bunkroom, a day room, a one man office which would also include room for a bunk, and an equipment room (for washer/dryer storage). Approximate square footage ranged from a minimum of about 2000 sq.ft. to an upper end near 3000 sq.ft. Any designs would include hook-ups for plumbing and electricity.

Next, it was necessary to find vendors that could provide such a service. This task involved contacting those people on-center who have had recent dealings with the erection of a prefabricated building. It was assumed that they would be able to provide names and numbers of vendors and, ideally, be able to provide vendor literature and brochures.

The most important and most challenging task involved placement of the facility. Any arrangement must provide direct access to the bay. This constraint, coupled with funding limitations, severely confined site development. The original idea was to erect the building on the "1247" side of the fire house, or the grassy area between the fire house and East Reid Street. However, upon investigation, it was discovered that many underground utilities converge in this area. These utilities included several electrical conduits, a 36" storm sewer with various connectors, two separate sets of telephone lines, and a buried headwall. An alternative was to place the building on the "1232" side over the existing parking area. This arrangement, however, would necessitate relocating the emergency generator and the condensing unit in addition to removing the asphalt parking surface. Moreover, providing direct access to the bay would necessitate cutting a hallway through the existing living space. All of these factors proved cost prohibitive. The last choice would be to go up -- add a modular second story. This option brings up the question of whether or not the foundation and the structural supports could accommodate the additional load.

Resolving all the aforementioned issues required extensive consultation with personnel in the Facilities and Systems Engineering Division and the construction services section of the Operations Support Division. Those consulted advised that building over the electrical lines is allowable, as long as the manhole is left accessible. As for the storm drain, it is possible to build over it, but it is not good engineering practice. If the pipe were to rupture, the resulting washout could collapse the building. Moving the drainage pipe was an alternative, but that option would prove superfluous and costly. With respect to going up, the present structure had not been engineered to accommodate a second floor. The resolution was to go with a long narrow structure, approximately 25 ft. by 70 ft. that would probably only provide the minimum accommodations of a bunkroom and a bathroom.

Once these issues were resolved, and while waiting to receive vendor information, time was spent sketching various arrangements. The 1800 or 1900 sq. ft. allowed inclusion of all but one of the desired elements. Depending on the configuration, either the dayroom, kitchen, or chief's office was sacrificed. Several contacts with building suppliers and erection firms were also made in order to determine a rough cost estimate. However, at this time, no pricing information has been delivered.