PROJECT ADMINISTRATION DATA SHEET

Project No. A-3363
Project Director: William Bulpitt
Sponsor: USAF, Warner Robins ALC/PMWVB
Robins AFB, GA 31098

Type Agreement: Delivery Order No. 0014 under BOA F09603-82-G-3367
Award Period: From 9/21/82 To 2/17/83 (Performance) 3/19/83 (Reports)
Sponsor Amount: Total Estimated: $14,967 8/17/83 Funded: $14,967 8/17/84
Cost Sharing Amount: $_____

Title: Door Redesign; Air Cargo Tactical Loader

ADMINISTRATIVE DATA

1) Sponsor Technical Contact:
   Mr. Rick Holmes
   WR-ALC/PMWVB
   Robins AFB, GA 31098
   (912) 926-6031

2) Sponsor Admin/Contractual Matters:
   ONR RR
   206 O'Keefe Bldg.
   GIT
   Atlanta, GA 30332

Defense Priority Rating: DO-C9d under DMS

Military Security Classification:

RESTRICTIONS

See Attached Gov't Supplemental Information Sheet for Additional Requirements.
Travel: Foreign travel must have prior approval – Contact OCA in each case. Domestic travel requires sponsor
   approval where total will exceed greater of $500 or 125% of approved proposal budget category.

Equipment: Title vests with Gov't

COMMENTS:

COPIES TO:
Research Administrative Network
Research Property Management
Accounting
Procurement/EES Supply Services
Research Security Services (Reports Coordinator (OCA))
GTRI
Library
Research Communications (2)
Project File
Other
Other
SPONSORED PROJECT TERMINATION/CLOSEOUT SHEET

Date __ 8__/10/84 __________

Project No. A-3363 __________

Includes Subproject No.(s) __________

Project Director(s) __________

Sponsor USAF, Warner Robins AFB, GA 31098 __________

Title Door Redesign; Air Cargo Tactical Loader __________

Effective Completion Date: __________

Grant/Contract Closeout Actions Remaining: __________

☐ None

☐ Final Invoice or Final Fiscal Report

☐ Closing Documents

☐ Final Report of Inventions

☐ Govt. Property Inventory & Related Certificate

☐ Classified Material Certificate

☐ Other __________

*Air Force Contracting Officer requested that Final Report be submitted since additional funding is not available to the fund the work and no further work is anticipated.

Continues Project No. __________

COPIES TO: __________

Project Director
Research Administrative Network
Research Property Management
Accounting
Procurement/EES Supply Services
Research Security Services
Reports Coordinator (OCA)

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GTRI
Research Communications (2)
Project File
Other I. Newton

COPIES TO: __________

Form OCA 60:1028
Mr. Rick Holmes  
WR-ALC/MMIRB  
Robins AFB, GA 31098

RE: Georgia Tech Project A-3363  
Cargo Loader Door Redesign

Dear Mr. Holmes:

The October progress report is attached. The major work for this time period has been the collection of pertinent technical information and the beginning of arrangements to obtain a sample door.

Please call me if you have any questions.

Sincerely yours,

Anthony Jape

AJ/jb

Enclosure
Project A-3363
CARGO LOADER DOOR REDESIGN

Progress Report - October 1982

Project work began in late October with the initial meeting with the sponsor on 10-22-82. Some of the necessary drawings and documentation have been obtained and arrangements have been made to acquire more.

We are making arrangements to obtain a sample door and perform a visual inspection of the loader in the field. We are planning to discuss the problems with operation and maintenance personnel who have firsthand experience with the equipment in order to better evaluate the exact nature of the problems.
Mr. Rick Holmes  
WR-ALC/MMIRB  
Robins AFB, GA 31098  

RE: Georgia Tech Project A-3363 - Cargo Loader Door Redesign  

Dear Mr. Holmes:  

The November progress report is attached. The major work for this time period has been the continuation of efforts to collect the pertinent technical information and the sample door.  

Please call me if you have any questions.  

Sincerely yours,  

Anthony Jape  

AJ/jb  

Attachment
The data list of all service parts for the vehicle was received this month. We are continuing with arrangements to acquire additional technical documentation. Efforts to obtain the sample door necessary to begin the redesign work continued this month. We are currently planning to await the notification of a shipping date for the door before scheduling the visual inspection of the loader in the field.
January 5, 1983

Mr. Rick Holmes
WR-ALC/MMIRB
Robins AFB, Georgia 31098

Re: Georgia Tech Project A-3363 - Cargo Loader Door Redesign

Dear Mr. Holmes:

The December progress report is attached. The major work for this time period has been the continuation of efforts to collect the pertinent technical information and the sample door.

Please call me if you have any questions.

Sincerely,

Anthony Udpe
Research Engineer

AJ:vg
Enclosure
Efforts to obtain the sample door and technical information necessary to begin the redesign work continued this month. We are currently planning to await the arrival of the door before scheduling the visual inspection of the loader in the field.
Mr. Rick Holmes  
WR-ALC/MMIRB  
Robins AFB, GA  31098  

RE: Georgia Tech Project A-3363 - Cargo Loader Door Redesign  

Dear Mr. Holmes:  

The January progress report is attached. The major work for this time period has been the continuation of efforts to obtain the sample door. Please call me if you have any questions.  

Sincerely,  

Anthony Jape  
Research Engineer  

Aj/jb  
Attachment
Efforts to obtain the sample door necessary to begin the redesign work continued this month. T.O. 36M2-3-28-2 was recently received. We are still planning to await the arrival of the sample door before scheduling the visual inspection of the loader in the field.
Mr. Rick Holmes  
WR-ALC/MMIRB  
Robins AFB, Georgia 31098

SUBJECT: Georgia Tech Project A-3363 - Cargo Loader Door Redesign

Dear Mr. Holmes:

The February progress report is attached. The sample door arrived this month and preparations were made for a field trip to inspect the failed components of the loaders at Pope AFB, North Carolina.

Please call me if you have any questions.

Sincerely,

Anthony D. Jape  
Research Engineer I

ADJ: vg

Enclosure
Project A-3363  
Progress Report - February 1983  
CARGO LOADER DOOR REDESIGN

The sample door was received this month and a thorough visual inspection was performed. The door was delivered with the window glass broken. Plans to fly to Pope AFB, North Carolina were made. This trip was to provide an opportunity to examine the machines in the damaged condition.

Two unsuccessful attempts to complete this trip were made this month, and I am currently planning to reschedule the trip for the earliest available time period in March.
On March 14, Georgia Tech personnel traveled to Pope AFB, North Carolina, to meet with Sergeant O.C. Salinas and perform a visual examination of the TAC Sergeant Salinas showed me the 6 TAC loaders based at Pope, and a thorough visual examination was made of the door and surrounding cab panels on each of these.

The following major problem areas were identified and found to be common to all of the loaders examined:

1) Severe cracking of the window frame, glass run and supports, resulting in loss or breakage of window glass. Most of the cracks are occurring in highly stressed areas including small radius bends and corners.

2) Loss of fasteners intended to retain major components of the door, resulting in extreme loss of rigidity. The loss of these fasteners appears to be partly due to vibration and partly due to failure and pullout of threaded inserts.

3) Failure of hinge and hinge fasteners to maintain alignment of door. The resulting misalignment of the door causes excessive wear and impact damage to the edges of the door and surrounding cab panels. The misalignment of the door is caused by two wear modes working in parallel. One mode is excessive looseness in the hinge caused by wear occurring in both the radial and axial directions. The major wear component was observed to be in the axial direction. Three different hinge designs were in use and each exhibited slightly different wear characteristics. The other wear mode is
radial and axial looseness caused by the hinge fasteners at the hinge to door and hinge to cab mounting points. The fasteners are being subjected to local stresses which exceed their capacity.

In addition to the preceding major problems, the following contributing factors were identified as having an impact on the failure of the doors.

1) Numerous fatigue cracks in the door and surrounding cab panels. This results in a general weakening and loss of rigidity in the whole structure, promoting rapid further deterioration of the structure. Many of these cracks are occurring at short radius bends and in highly stressed support bracing.

2) A general lack of rigidity in the cab panels that mount the door and the latch striker plate. This is a result of fractured components, loose or sheared rivets, and a lack of sufficient bracing of the cab panels surrounding the door opening.

These problems are important in that they occur independently of the problems occurring within the door, and they can independently cause door failure. The entire cab structure is suffering from the same basic problems as the door and the door problems cannot be completely solved without addressing some of the contributing factors in the surrounding cab panels.

3) A lack of carefully placed assist handles and steps for personnel to enter cab results in excessive force being applied to the door and hinge structure on certain occasions. The detachable step provided with the vehicle is not sufficient
to provide easy access to the cab. An improved access arrangement that would allow personnel to enter the cab without applying significant force to the door would greatly increase the life of the door and hinge assembly.

Next month we are planning to disassemble the sample door and study the problem areas in light of the information gained during the visual inspection. We are going to prioritize these problem areas and develop some potential solutions for each one.
Mr. Rick Holmes  
WR-ALC/MMTRA  
Robins AFB, GA 31098  

Subject: Georgia Tech Project A-3363, Cargo Loader Door Redesign  

Dear Mr. Holmes:  

The May progress report is attached. The new sample door was disassembled this month and plans for testing and evaluation of some failure modes were formulated.  

Please call me if you have any questions.  

Sincerely,  

Anthony Jape  

AJ/Imk  
Att
The sample door was disassembled for detailed study this month. The component pieces and attaching hardware that had been identified as being within problem areas by the field inspection were examined in the new condition. The most serious failure mode has been determined to be the formation of cracks found in numerous components. Next is the failure of fasteners and other retaining hardware. The following analysis is planned to get to the root of the cracking problem.

Step 1: Check the new pieces for conformity with the drawings in the area of bend radius at all critical bends. Compare the findings with design data for the materials used and conditions experienced.

Step 2: Obtain a sample of a failed door and perform tests to determine the origin and type of cracks found. A number of samples will be cut from the door for this purpose. Samples will be cut from unfailed areas and tests will be performed to determine the mechanical properties of the part as fabricated.

The information obtained from these tests will be very beneficial in trying to eliminate the cracking problem from the new design.
Mr. Rick Holmes  
WR-ALC/MMTRA  
Robins AFB, GA  31098  

Subject: Georgia Tech Project A-3363, Cargo Loader Door Redesign  

Dear Mr. Holmes:  

The June progress report is attached. No charges were incurred or work performed this month. We expect to resume work at the normal rate next month.  

Please call me if you have any questions.  

Sincerely,  

Anthony Jape  

AJ/lmk
Due to the allocation of personnel to projects requiring completion by the fiscal year end in June, no charges were incurred or work performed on A-3363 this month. We are planning to resume work at the normal rate in July.
Mr. Rick Holmes  
WR-ALC/MMTRA  
Robins AFB, GA  31098

Subject: Georgia Tech Project A-3363, Cargo Loader Door Redesign

Dear Mr. Holmes:

The July progress report is attached. We obtained and disassembled a used sample door this month. The Georgia Tech Fracture and Fatigue Research Laboratory will be assisting us in the evaluation of the problems we found in the used sample door.

Please call me if you have any questions.

Sincerely,

Anthony Jape

AJ/pk

Attachment
On July 15, 1983, Georgia Tech personnel traveled to Pope AFB, North Carolina, and obtained a sample of a failed loader door. The damaged door has been disassembled and the Georgia Tech Fracture and Fatigue Research Laboratory has prepared an outline of the work that will be required to properly document the material properties and the nature of the failures.

The bend radii on a number of major areas was measured and checked against the drawings. Some differences between the drawings and actual part were found, but we should wait for the report from the Fracture and Fatigue Lab before interpreting this data.

The additional documentation required to address some of the window frame and cab problems was requested this month. Documentation covering the M-35 2½ ton 6x6 was also requested. This vehicle uses a window regulator which may be suitable for use in the redesigned loader door. The manuals requested should give additional information about these parts and provide the information needed to request the parts needed from the Air Force supply system.
Mr. Rick Holmes  
WR-ALC/MMTRA  
Robins AFB, GA 31098

Subject: Georgia Tech Project A-3363, Cargo Loader Door Redesign

Dear Mr. Holmes:

The August progress report is attached. The major work for this period was the preparation and submittal of an expanded work statement to cover the problems found in the Cab that were interrelated to the door problems. Also, as we discussed on the telephone, I have requested a 6 month extension of the contract expiration date. This will allow the project to continue while we wait for word on the expanded work statement.

Please call me if you have any questions.

Sincerely,

Anthony Jape  
Research Engineer

AJ/pk

Attachment
The major work accomplished this month was the preparation and submittal of an expanded work statement for the project. As detailed in the April 1983 progress report, a number of problems were found to exist in the cab panels surrounding the door. These problems were found to be interrelated with the door problems we are addressing with this project. The expanded work statement details a plan and budget required to address the cab problems concurrently with the door redesign. The expected outcome of this additional work is the design and prototype construction of a field installable bracing kit that will greatly improve the life and performance of the door mounting and surrounding area of the cab.

The funds and time remaining for the door redesign work are running low and next month we will address this problem in detail. I have requested a 6 month extension of the expiration date of the contract to keep it active while awaiting a decision on the expanded work statement.
Mr. Rick Holmes  
WR-ALC/MMTRA  
Robins AFB, GA  31098

Subject: Georgia Tech Project A-3363, Cargo Loader Door Redesign

Dear Mr. Holmes:

The September progress report is attached. The project budget and status were studied in detail this month. An estimate of the additional funds required to complete the work was prepared and submitted.

The 6 month extension and new deliverables schedule was received this month.

Please call me if you have any questions.

Sincerely,

Anthony Jape  
Research Engineer

AJ/pk

Attachment
The project budget and status was studied in detail this month. It was determined that the following occurrences have caused a more rapid consumption of the budget than was originally planned:

1. Long lead times and delays in obtaining sample parts and documentation.

2. The problems with fasteners and structural rigidity were more widespread than originally thought.

3. The problems with cracking of the alloy materials were more prevalent and difficult to handle than was originally supposed.

4. The cracking problems created a need to extensive fracture and fatigue analysis work which was not included in the original budget estimate.

A plan has been formulated to carry the door redesign work to completion. The plan consists of the following basic steps:

1. Obtain a sample of a damaged door from the military and have the Georgia Tech Fracture and Fatigue Research Laboratory perform an analysis to determine the material properties and the nature and type of cracking present. This is necessary due to the difficulty of designing light alloy structures to perform in the environment that the Tac Loader operates in.
2. Select and obtain alloy materials assisted by information gained in step 1.

3. Locate and obtain sample of a suitable window regulator for the door.

4. Redesign window frame and door to increase rigidity as necessary and incorporate new regulator and redesigned window guides.

5. Construct prototype using parts from old door where possible and constructing new parts as required.

6. Prepare documentation package.

Based on currently available information, the time required to complete the above tasks has been estimated as follows:

1. Mostly complete. The Fracture Laboratory is ready to begin on our notification to proceed.

2. ½ week.

3. ½ week.

4. 2 weeks.

5. 3 weeks.

6. 2 weeks.

A Student Assistant will be required approximately 50% for steps 2-5 and 100% to do the drafting in step 6. The Fracture Laboratory has estimated their part at $4,225. In accordance with the above time estimates, the total cost to complete the work has been estimated at $21,545.
A detailed proposal based on the above estimates was prepared and submitted this month.

The 6 month extension and new deliverables schedule was received this month.
November 10, 1983

Mr. Rick Holmes
WR-ALC/MMTRA
Robins AFB, GA 31098

Subject: Georgia Tech Project A-3363, Cargo Loader Door Redesign

Dear Mr. Holmes:

The October progress report is attached. We are basically trying to conserve funds while waiting for word on the expanded work statement and additional funds we previously discussed.

Please call me if you have any questions.

Sincerely,

Anthony Jâpe
Research Engineer

AJ/pk
Attachment
Due to the small amount of funds remaining in the budget, charges and work have been kept to a minimum this month. We are trying to conserve the remaining funds while waiting for word on the additional work and funds that were recently requested. A response to my letter of July 21, 1983 was received this month. This letter answers my questions about alloy selection, detachability of the window frame, and weight consideration.
February 28, 1984

Mr. Rick Holmes  
WR-ALC/MMTRA  
Robins AFB, GA 31098

Subject: Georgia Tech Project A-3363, Cargo Loader Door Redesign

Dear Mr. Holmes:

The November, December, and January progress reports for the inactive A-3363 project are attached. While waiting for further notice on the expanded work statement and the additional funds discussed earlier, we are conserving the small amount of the original funds remaining. Also, as we discussed in our telephone conversation today, I have requested a 6 month extension of the project. This will allow the continuation of the project while we wait for word on the expanded work statement.

Please call me if you have any questions.

Sincerely,

Anthony Jape  
Research Engineer

ADJ/pk
Attachments
Due to the small amount of funds remaining in the budget, no further work has been performed. At present, we are awaiting the needed funding to continue with the project.
Final Report
Project No. A—3363

TAC LOADER DOOR REDESIGN

Prepared by:
Anthony D. Jape
Project Director

Submitted to:
Warner Robins Air Logistics Center
Robins Air Force Base, Georgia

May 1984

GEORGIA INSTITUTE OF TECHNOLOGY
A Unit of the University System of Georgia
Engineering Experiment Station
Atlanta, Georgia 30332
Project No. A-3363

TAC LOADER DOOR REDESIGN

Final Report

Submitted to:
Warner Robins Air Logistics Center
Robins Air Force Base, Georgia

Prepared by:
Anthony D. Jape
Project Director

Engineering Experiment Station
GEORGIA INSTITUTE OF TECHNOLOGY
Atlanta, Georgia  30332

May 1984
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# LIST OF ILLUSTRATIONS

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I. Introduction

The Georgia Tech Engineering Experiment Station, under contract to the Warner Robins Air Logistics Center, conducted an investigation into the structural failure of cab doors on the model A/S 32H-19 Aircraft Cargo Loading/Unloading Truck. The initially stated scope of activity for this study included the following tasks:

- Inspection of doors installed on loaders and discussion with Air Force personnel as to difficulties encountered in service.
- Detailed examination of a failed door unit.
- Redesign of the door to solve the problem of structural failures.
- Construction and testing of a prototype door.
- Preparation of documentation on the redesigned door.

Several difficulties were encountered in obtaining information and specimen doors in a timely manner. In addition, the study revealed that there are numerous failure points on the
doors and that design flaws in the door were only a part of overall structural design inadequacies in the cab.

For these reasons, a complete redesign of the entire cab structure was considered warranted. As an interim measure, a modified scope of work was proposed, involving development of a field modification kit. The proposed kit would provide adequate structural improvements to both the cab and the door to alleviate the unsatisfactory performance. The statement of work for this proposal is presented in Appendix A.

The sponsor elected not to pursue this solution to the problem and instead to end the project and pursue other alternatives. This report summarizes the activities and findings of the work completed under the contract.
II. Background

The A/S 32H-19 truck is a special purpose vehicle designed for flexibility in loading and unloading cargo at various heights to and from aircraft at terminal docks. The truck deck will adjust in both height and tilt in order to accommodate various loading requirements. In addition, the truck is capable of on- and off-loading cargo from its deck to the ground with winches. In its basic configuration, the truck has a load capacity of 25,000 pounds of palletized cargo. The truck is illustrated in Figure 1.

The one-man cab is located on the left forward side of the truck and is attached to the deck so as to raise and lower with the load. The cab may be swung inward to a stowed position in which it does not extend beyond the edge of the deck. This position is used for air shipment and road travel.

Two folding steps and two handgrips are located on the left rear side of the cab wall, and a grab handle is located on the rear cab wall. These are intended to aid entry to both the cab and the cargo deck catwalk. A portable step is provided for use in entering the cab. It is transported in the cab and secured behind the seat.
Figure 1. A/S 32H-19 CARGO LOADER
The cab door, illustrated in Figure 2, consists primarily of two sheet metal panels, a window rim attached with screws, the window glass, window operating mechanism, and the handle/latch mechanism.
III. Description of the Problem

The cab door has been a continuing source of difficulty, with numerous service failures having been encountered. Discussions with Air Force personnel indicated that the doors experience substantial damage during their first year of use with continuing deterioration afterward. The failures are due to design inadequacies, so that there is no satisfactory field repair technique, and even complete replacement of the door offers only a temporary solution. As a result, doors regularly remain in use after they reach an unserviceable condition.

Georgia Tech personnel performed a visual examination of the six TAC loaders based at Pope Air Force Base, North Carolina. Several major problem areas were identified and found to be common to all of these loaders:

- Severe cracking of the window frame, glass run and supports, resulting in loss or breakage of the glass.

- Loss of fasteners intended to retain major components of the door, resulting in extreme loss of rigidity.

- Failure of the hinge and hinge fasteners to maintain
alignment of the door.

Most of the cracks occur in highly stressed areas, including small radius bends and corners. This finding suggested the need for failure mode analyses to determine whether the components experienced excessive stresses during fabrication or service or perhaps failed due to cyclical stress fatigue. Such testing was proposed as part of an expanded scope of work.

The lack of a continuous door frame severely limits the structural rigidity which can be attained. The design assumes that rigidity is derived from the components being securely fastened to form a shell. The two door panels are held together with screws, many of which were found to be missing, possibly due to vibration. Many of the threaded inserts which anchor these screws fail or pull out of their mounting points.

Misalignment of the door causes substantial wear and impact damage to the edges of the door and the surrounding cab panels. The misalignment is caused both by radial and axial wear in the hinge and by looseness in the hinge-to-door and hinge-to-cab mounting points. The fasteners at these mounting points are being subjected to local stresses which exceed their capacity.

In addition to these major problems, several contributing factors were identified as having an impact on the failure of the doors:
- Numerous cracks not only in the door panels but also in the surrounding cab panels. The loss of rigidity which results promotes further deterioration of the structure.

- Inadequate assist handles and steps for personnel to enter the cab. The detachable step is not convenient, while the door itself is an attractive assist handle. The loads applied to the door and hinges exceed the capacity of the design.

- A general lack of rigidity in the cab panels that mount the door and the latch striker plate. This is the result of failed cab components, loose or sheared rivets, and insufficient bracing of the panels.

These problems are important because they contribute to the failure of the door. Even if the door design is improved, the weaknesses in the design of the cab will lead to excessive door failures.
IV. Further Investigations

The initial scope of the study called for a detailed examination of a failed door unit. Considerable difficulty and delay was encountered in obtaining the specimen. As a substitute, a new door was obtained for examination five months after the start of the project. This door was disassembled and subjected to a preliminary examination. The fact that it had not been exposed to service and did not exhibit indications of typical failure modes limited the usefulness of the unit to the study.

Five months later, a used door was obtained and subjected to preliminary examinations. Since cracking had been observed near small radius bends on many doors in service, the match between specified and as-built radii was a primary concern. Table 1 presents the specified bend radii for several locations as well as the radii measurements for the used door.

Three of the four radii on the window frame bracket and gusset were approximately 40% less than the design specification. Bends on the door panels were approximately 20% sharper than specified. Other bends were measured at very near the specified radii.
Table 1. Specified and Measured Bend Radii

<table>
<thead>
<tr>
<th>Position of Radius</th>
<th>Specified (inches)</th>
<th>Measured (inches)</th>
<th>*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Window frame bracket</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>rear</td>
<td>0.13</td>
<td>5/64 (.078)</td>
<td></td>
</tr>
<tr>
<td>front</td>
<td>0.13</td>
<td>1/8 (.125)</td>
<td></td>
</tr>
<tr>
<td>Window frame gusset</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>rear</td>
<td>0.13</td>
<td>5/64 (.078)</td>
<td></td>
</tr>
<tr>
<td>front</td>
<td>0.13</td>
<td>5/64 (.078)</td>
<td></td>
</tr>
<tr>
<td>Window support bracket</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>&quot;L&quot; portion</td>
<td>0.06</td>
<td>3/64 (.047)</td>
<td></td>
</tr>
<tr>
<td>&quot;Z&quot; portion</td>
<td>0.06</td>
<td>1/16 (.063)</td>
<td></td>
</tr>
<tr>
<td>Inside door panel</td>
<td>0.08</td>
<td>1/16 (.063)</td>
<td></td>
</tr>
<tr>
<td>Outside door panel</td>
<td>0.08</td>
<td>1/16 (.063)</td>
<td></td>
</tr>
<tr>
<td>Window stop</td>
<td>0.12</td>
<td>1/8 (.125)</td>
<td></td>
</tr>
</tbody>
</table>

* Radii were measured with a radius gage to 1/64 inch precision. Decimal equivalents are presented only for convenience in comparison.
Plans were developed to conduct detailed analyses of the failure mode of the door, to aid in developing an improved design. The Georgia Tech Fracture and Fatigue Research Laboratory prepared a test plan to be performed on specimens cut from the door. Tests to be conducted included:

- Tensile tests to determine mechanical properties.

- Optical metallography.

- Bend tests to determine the appropriateness of the material used.

- Scanning electron microscope examination to determine failure mechanism (fatigue vs. tensile overload).

Since these tests exceeded the limits of the original study and would require additional funding, they were included in the proposal submitted to the sponsor for an expanded study. Since the additional work has not been contracted, the failure analyses have not been performed.
V. Recommendations

A proposal was submitted to the sponsor for development of a field installation kit which would alleviate difficulties with the cab and door structural performance. A preferred alternative is the complete redesign of the cab assembly.

The expanded scope of work also included investigations which were designed to develop a data base adequate for proper redesign of the door and/or cab. Finalizing these data is recommended if a redesign is eventually undertaken in order to avoid recurrence of the same problems.

In considering opportunities for design improvement, several potential barriers were identified, and clarification was requested on design constraints. Future designers should be advised of the responses to these requests.

The first topic involved material selection, acceptable alloys, and heat treatment processes. Use of light alloys is encouraged by the need to air lift the vehicle, but it also complicates the structural design process. The response which was received indicated that there were no restrictions on alloy and heat treatment selection except that the material must be
easily available.

The second topic involved permissible weight increases which might be required to obtain adequate structural integrity. The response indicated that a maximum weight increase of 15 pounds for the door was acceptable. A weight increase associated with a redesign of the entire cab was not addressed.

Finally, the lack of an integral frame for the window and door restricts the rigidity which can be achieved. It appears that the frame was omitted from the design in order to allow the vehicle to be converted to a reduced-overall-height configuration by removal of the cab roof. The response received on this inquiry stated that an integral door/window frame was acceptable and that it is not necessary for the window frame to be detachable, provided there is a means to replace the window glass.

The response to this third inquiry, by eliminating the need for the reduced-height mode, suggests that a unitized cab body/roof may be an acceptable design. Such a configuration could contribute substantially to the rigidity and structural durability of the cab and door.

In fact, it appears that such a design was developed at one time. A prototype of such a cab was observed at Pope Air Force Base, where it had been considered for local modification and installation. Georgia Tech does not have access to the entire
development history of the vehicle design, so the deficiencies and objections to the rigid cab design cannot be evaluated. However, the prototype which was observed appeared to offer numerous structural advantages over the current design and should be preferred if there is no requirement for operating the vehicle at a reduced height.

Development of a field installation kit is a viable alternative as an intermediate solution to the design weaknesses in the cab. Although such a kit has not been developed under this project and the modifications necessary in the door design have not been completely analyzed, several areas have been identified to which specific attention must be paid. These observations are presented as an aid in the event that such an intermediate solution is eventually undertaken:

1. Fasteners must be improved. The hinge is attached to the door and the cab with pop rivets -- a fastener type which is not suitable for supporting significant shear loads. Pop rivets are also used to attach many of the minor components to the door panels. Screwed fasteners which hold the door panels together are anchored with pop-in threaded inserts. These inserts are not secure. They rotate in place, preventing adequate tightening of the screws, while they will pull out completely if significant loads are applied. Two recommended methods are the use of
a backing bar to serve as the anchor for threaded fasteners and the use of conventional, driven rivets to form permanent attachments.

2. The quality of the hinge itself must be improved. Several hinge types are in use, most of which employ light weight alloys which are not heat treated. The added weight of a steel hinge may well be rewarded with improved performance.

3. The window guides and lift mechanism are not adequate to maintain proper orientation of the glass. As a minimum, the lift mechanism should be replaced with one which provides two separated lift points rather than the current single point.

4. The outside door handle and handle cup are not securely attached. Adequate provisions for holding the cup in place will improve performance.

5. The bend radii on the door panels should be increased to match the acceptable applications for the alloy used. These increases should appear not only in the drawings, but more importantly in the actual fabrication.

6. The window frame should be an integral part of the door. This may not be possible in a limited redesign, in which case a much more secure means of attaching the removable
frame should be implemented.

7. Improved means should be provided for access to the cab. The removable steps are inconvenient and encourage the use of the open door as a handle for climbing in. This maneuver places excessive loads on the hinge and mounting points. A permanently-mounted, retractable ladder that can be easily positioned from both the ground and the cab should be considered as a candidate solution to this problem.
Appendix A

SCOPE OF PROPOSED ADDITIONAL WORK
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The original statement of work consisted of the following five steps:

1. **Inspection** -- Final inspection of the problem doors and discussions with Air Force personnel.

2. **Example Procurement** -- If possible, an example of the problem door will be obtained and brought to Georgia Tech for further inspection.

3. **Redesign** -- Components of the door will be redesigned to solve the problems with hinges, window rigidity and window operation.

4. **Prototype Construction** -- Fabrication, test and evaluation using example door as base.

5. **Drawings, Documentation** -- A complete set of drawings will be prepared to document the redesign of the door to solve the problems and a brief final report will be prepared to explain the findings.

To perform Step 1, Georgia Tech personnel traveled to Pope AFB, North Carolina, to meet with Sergeant O. C. Salinas and perform a visual examination of the TAC loader. Sergeant Salinas showed us the 6 TAC loaders based at Pope, and a thorough visual examination was made of the door and surrounding cab panels on each of these.

The following major problem areas were identified and found to be common to all of the loaders examined:

1. Severe cracking of the window frame, glass run and supports, resulting in loss or breakage of window glass. Most of the cracks are occurring in highly stressed areas, including small radius bends and corners.

2. Loss of fasteners intended to retain major components of the door, resulting in extreme loss of rigidity. The loss of these fasteners appears to be partly due to vibration and partly due to failure and pullout of threaded inserts.

3. Failure of hinge and hinge fasteners to maintain alignment of the door. The resulting misalignment of the door causes
excessive wear and impact damage to the edges of the door and surrounding cab panels. The misalignment of the door is caused by two wear modes working in parallel. One mode is excessive looseness in the hinge caused by wear occurring in both the radial and axial directions. The major wear component was observed to be in the axial direction. Three different hinge designs were in use and each exhibited slightly different wear characteristics. The other wear mode is radial and axial looseness caused by the hinge fasteners at the hinge to door and hinge to cab mounting points. The fasteners are being subjected to local stresses which exceed their capacity.

In addition to the preceding major problems, the following contributing factors were identified as having an impact on the failure of the doors:

1. Numerous fatigue cracks in the door and surrounding cab panels. This results in a general weakening and loss of rigidity in the whole structure, promoting rapid further deterioration of the structure. Many of these cracks are occurring at small radius bends and in highly stressed support bracing.

2. A lack of carefully placed assist handles and steps for personnel to enter cab results in excessive force being applied to the door and hinge structure on certain occasions. The detachable step provided with the vehicle is not sufficient to provide easy access to the cab. An improved access arrangement that would allow personnel to enter the cab without applying significant force to the door would greatly increase the life of the door and hinge assembly.

3. A general lack of rigidity in the cab panels that mount the door and the latch striker plate. This is a result of fractured components, loose or sheared rivets, and a lack of sufficient bracing of the cab panels surrounding the door opening.

These problems are important in that they occur independently of the problems occurring within the door, and they can independently cause door failure. The entire cab structure is suffering from the same basic problems as the door, and the door problems cannot be completely solved without addressing some of the contributing factors in the surrounding cab panels.

In order to provide an effective solution to the problems enumerated above, we propose to expand the statement of work to include the cab to the extent necessary to address its most serious problems. The expanded work statement would consist of
the following five steps:

1. **Inspection** -- Additional inspection of the cab and discussions with Air Force personnel will be required.

2. **Example Procurement** -- Samples of a damaged and an undamaged door have already been procured. A sample of a damaged cab assembly would greatly improve the speed and allow greater detail in the redesign work.

3. **Redesign** -- Components of the door will be redesigned to solve the problems with hinges, window operation and general rigidity. For the cab, we are planning to design a retrofit package consisting of redesigned components and additional structural bracing that can be field installed. We are also planning to investigate some alternative methods for improving operator access to the cab. It is believed that this will result in the design of a field installable retrofit package that will significantly improve operator access to the cab.

4. **Prototype Construction** -- Fabrication, test and evaluation using example door and cab as base.

5. **Drawings, Documentation** -- A complete set of drawings will be prepared to document the redesign of the door and cab structure. A brief final report will be prepared to explain the findings.