

AD-A220 360

WRDC-TR-89-3118



FORWARD CANOPY FEASIBILITY AND
THRU-THE-CANOPY (TTC) EJECTION SYSTEM STUDY

James W. Myers
PPG Industries, Inc.
Aircraft Products Division
P. O. Box 2200
Huntsville, Alabama 35804

January 1990

Final Report for Period December 1981 - September 1989

Approved for public release; distribution is unlimited

DTIC
ELECTE
APR 11 1990
S D
D

FLIGHT DYNAMICS LABORATORY
WRIGHT RESEARCH AND DEVELOPMENT CENTER
AIR FORCE SYSTEMS COMMAND
WRIGHT-PATTERSON AIR FORCE BASE, OHIO 45433-6553

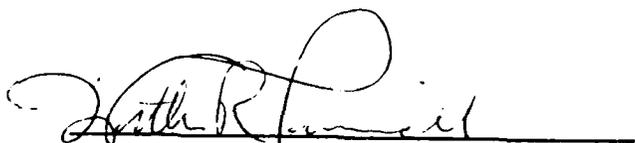
90 0 0 0 19

NOTICE

WHEN GOVERNMENT DRAWINGS, SPECIFICATIONS, OR OTHER DATA ARE USED FOR ANY PURPOSE OTHER THAN IN CONNECTION WITH A DEFINITELY GOVERNMENT-RELATED PROCUREMENT, THE UNITED STATES GOVERNMENT INCURS NO RESPONSIBILITY OR ANY OBLIGATION WHATSOEVER. THE FACT THAT THE GOVERNMENT MAY HAVE FORMULATED OR IN ANY WAY SUPPLIED THE SAID DRAWINGS, SPECIFICATIONS, OR OTHER DATA, IS NOT TO BE REGARDED BY IMPLICATION, OR OTHERWISE IN ANY MANNER CONSTRUED, AS LICENSING THE HOLDER, OR ANY OTHER PERSON OR CORPORATION; OR AS CONVEYING ANY RIGHTS OR PERMISSION TO MANUFACTURE, USE, OR SELL ANY PATENTED INVENTION THAT MAY IN ANY WAY BE RELATED THERETO.

THIS REPORT HAS BEEN REVIEWED BY THE OFFICE OF PUBLIC AFFAIRS (ASD/PA) AND IS RELEASABLE TO THE NATIONAL TECHNICAL INFORMATION SERVICE (NTIS). AT NTIS IT WILL BE AVAILABLE TO THE GENERAL PUBLIC INCLUDING FOREIGN NATIONS.

THIS TECHNICAL REPORT HAS BEEN REVIEWED AND IS APPROVED FOR PUBLICATION.

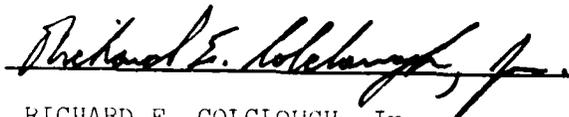


WILLIAM R. PINNELL
Project Engineer
T-38 Project



WALLACE C. BUZZARD, Chief
Aircrew Protection Branch
Vehicle Subsystems Division

FOR THE COMMANDER



RICHARD E. COLCLOUGH, Jr.
Chief
Vehicle Subsystems Division

IF YOUR ADDRESS HAS CHANGED, IF YOU WISH TO BE REMOVED FROM OUR MAILING LIST, OR IF THE ADDRESSEE IS NO LONGER EMPLOYED BY YOUR ORGANIZATION PLEASE NOTIFY WRDC/FIVR, WRIGHT-PATTERSON AFB, OH 45433-6553 TO HELP MAINTAIN A CURRENT MAILING LIST.

COPIES OF THIS REPORT SHOULD NOT BE RETURNED UNLESS RETURN IS REQUIRED BY SECURITY CONSIDERATIONS, CONTRACTUAL OBLIGATIONS, OR NOTICE ON A SPECIFIC DOCUMENT.

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE

REPORT DOCUMENTATION PAGE

1a. REPORT SECURITY CLASSIFICATION UNCLASSIFIED			1b. RESTRICTIVE MARKINGS		
2a. SECURITY CLASSIFICATION AUTHORITY			3. DISTRIBUTION / AVAILABILITY OF REPORT Approved for public release; distribution unlimited.		
2b. DECLASSIFICATION / DOWNGRADING SCHEDULE					
4. PERFORMING ORGANIZATION REPORT NUMBER(S) PPG-CDRL-6			5. MONITORING ORGANIZATION REPORT NUMBER(S) WRDC-TR-89-3118		
6a. NAME OF PERFORMING ORGANIZATION PPG Industries, Inc. Aircraft Products Division		6b. OFFICE SYMBOL (if applicable)	7a. NAME OF MONITORING ORGANIZATION Wright Research and Development Center Flight Dynamics Laboratory (WRDC/FIVR)		
6c. ADDRESS (City, State, and ZIP Code) P. O. Box 2200 Huntsville, Alabama 35804			7b. ADDRESS (City, State, and ZIP Code) WPAFB, OH 45433-6553		
8a. NAME OF FUNDING / SPONSORING ORGANIZATION		8b. OFFICE SYMBOL (if applicable)	9. PROCUREMENT INSTRUMENT IDENTIFICATION NUMBER F33615-81-C-3403		
8c. ADDRESS (City, State, and ZIP Code)			10. SOURCE OF FUNDING NUMBERS		
			PROGRAM ELEMENT NO. 64212F	PROJECT NO. 1926	TASK NO. 01
11. TITLE (Include Security Classification) Forward Canopy Feasibility and Thru-The-Canopy (TTC) Ejection System Study					
12. PERSONAL AUTHOR(S) James W. Myers					
13a. TYPE OF REPORT Final		13b. TIME COVERED FROM 12/81 TO 9/89		14. DATE OF REPORT (Year, Month, Day) 1990, January	15. PAGE COUNT 160
16. SUPPLEMENTARY NOTATION					
17. COSATI CODES			18. SUBJECT TERMS (Continue on reverse if necessary and identify by block number) Thru-The-Canopy Ejection System Pin Pull System Clear Path Egress System Sill Cutting System Shielded Mild Detonating Cord		
FIELD	GROUP	SUB-GROUP			
01	03				
19. ABSTRACT (Continue on reverse if necessary and identify by block number) This study presents the development and production of a half scale forward canopy to integrate bird strike protection for the T-38 aircraft. Actual half scale T-38 forward canopy fabrication process and production procedures are included in this report. Forward canopy cross sections that should provide the desired bird strike protection level as recommended by the University of Dayton Research Institute (UDRI) and PPG Industries, Inc. are included. A detailed final report on the T-38 Clear Path Egress (CPE) System by Space Ordnance Systems (SOS), which includes technology assessment and concept review of six systems is also included. Integration of the forward canopy, the T-38 airframe, and thru-the-canopy (TTC) escape capability systems have been mechanically and economically considered.					
20. DISTRIBUTION / AVAILABILITY OF ABSTRACT <input checked="" type="checkbox"/> UNCLASSIFIED/UNLIMITED <input type="checkbox"/> SAME AS RPT. <input type="checkbox"/> DTIC USERS			21. ABSTRACT SECURITY CLASSIFICATION UNCLASSIFIED		
22a. NAME OF RESPONSIBLE INDIVIDUAL Lt. Tong C. Choe, William R. Pinnell			22b. TELEPHONE (Include Area Code) (513) 255-6524		22c. OFFICE SYMBOL WRDC/FIVR

SUMMARY

This study presents the development and production of a half scale forward canopy to integrate bird strike protection for the T-38 Aircraft. Actual half scale T-38 Forward Canopy fabrication process and production procedures are included in this report. Forward canopy cross sections that should provide the desired Bird Strike Protection level as recommended by the University of Dayton Research Institute (UDRI) and PPG Industries, Inc. are included. A detailed final report on the T-38 Clear Path Egress (CPE) System by Space Ordnance systems (SOS), which includes technology assessment and concept review of six systems is also included. Integration of the forward canopy, the T-38 airframe and thru-the-canopy (TTC) escape capability systems have been mechanically and economically considered.

PPG's recommended cross section for full scale development activities would be the laminated two plies of 0.125 inch polycarbonate with 0.060 inch interlayer faced with 0.030 inch PPG 5300 liner outboard and abrasion resistant coating inboard.

SOS's recommendations for Initiation Systems should Detailed Design Development be pursued are The Redundant Gas Initiation and Cable Ground Egress, Canopy Mounted and The Dual Gas Initiation with Cable Ground Egress.

SOS's recommendations for Severance and Canopy Removal Concepts should Detailed Design Development be pursued are The Side and Rear Flexible Linear Shaped Charge (FLSC) Severance with Seat Mounted Pusher and The Side and Rear Severance using Edge Imbedded Mild Detonating Fuse (MDF) with Seat Mounted Pusher.

TABLE OF CONTENTS

	PAGE
1.0 INTRODUCTION	1
2.0 FORWARD CANOPY.....	3
2.1 Statement of the Problem.....	3
2.1.1 <u>Canopy System Bird Impact Resistance</u>	3
2.1.2 <u>Canopy and TTC System Weight</u>	5
2.2 Problem Attack.....	8
2.2.1 <u>TTC Concept Selection</u>	8
3.0 T-38 FORWARD CANOPY FABRICATION PROCESS.....	10
3.1 T-38 Forward Canopy Fabrication Procedure.....	10
3.2 Chemically Tempered Glass Pressing Plate Preparation.....	18
3.2.1 <u>Material and Equipment Required</u>	18
3.2.2 <u>Procedure</u>	18
3.3 Polycarbonate Blank Preparation.....	19
3.3.1 <u>Material and Equipment Required</u>	19
3.3.2 <u>Procedure</u>	19
3.4 Press Polishing Polycarbonate.....	20
3.4.1 <u>Material and Equipment Required</u>	20
3.4.2 <u>Assembly Procedure</u>	21
3.4.3 <u>Polymer Bagging Procedure</u>	23
3.4.4 <u>Autoclave Press Polishing Cycle</u>	23
3.4.5 <u>Post Press Polish Stripping</u> ..	23
3.5 Dow Corning Sylgard 184 Application...	24
3.5.1 <u>Material and Equipment Required</u>	24
3.5.2 <u>Sylgard 184 Preparation Procedure</u>	24

TABLE OF CONTENTS (Concluded)

	PAGE
3.5.3 <u>Polycarbonate Blank Preparation</u>	25
3.6 Canopy Preforming Procedure.....	26
3.6.1 <u>Material and Equipment Required</u>	26
3.6.2 <u>Procedure</u>	27
3.7 Vacuum Tool Clean-Up and Side Extension Sealing.....	28
3.7.1 <u>Material and Equipment Required</u>	28
3.7.2 <u>Procedure</u>	28
3.8 Preform Insertion, Clamping, and Instrumentation.....	30
3.8.1 <u>Material and Equipment Required</u>	30
3.8.2 <u>Installation of Preform Into Vacuum Fixture</u>	30
3.8.3 <u>Clamping Arch Rings and Side Bars</u>	30
3.8.4 <u>Thermocouple Application</u>	31
3.9 Final Forming.....	32
3.9.1 <u>Material and Equipment Required</u>	32
3.9.2 <u>Vacuum Forming</u>	32

APPENDIX.....



Acoesion For	
NTIS CRA&I	<input checked="" type="checkbox"/>
DTIC TAB	<input type="checkbox"/>
Unannounced	<input type="checkbox"/>
Justification	
By _____	
Distribution /	
Availability Codes	
Dist	Avail and/or Special
A-1	

LIST OF ILLUSTRATIONS

Figure		Page
1	Forward Canopy Bird Impact Locations.....	4
2	Forward Canopy Cross Sections.....	7
3	Canopy Pre-Form Tool With Attached Polycarbonate.	11
4	Polycarbonate Pre-Formed On Forming Tool.....	12
5	Pre-Formed Polycarbonate Canopy.....	13
6	Subscale Canopy Vacuum Forming Fixture.....	14
7	Pre-Formed Polycarbonate Clamped In Forming Fixture.....	16
8	Formed Canopy.....	17

1.0 INTRODUCTION

This study includes the feasibility of development and production of a forward canopy for the T-38 aircraft which integrates improved bird impact protection while maintaining present optical and durability characteristics with thru-the-canopy (TTC) escape capability. The canopy design shall provide bird strike resistance with a nominal 4 pound weight bird at an impact velocity of 400 knots and have a secondary mode of emergency escape. The design should allow thru-the-canopy (TTC) ejection of the occupied T-38 forward ejection seat. The primary escape mode would still be jettison of the canopy before ejection. Two alternative methods to provide emergency ground egress capability if normal canopy opening is not feasible have been evaluated. The current method used to provide this capability is a hand held Canopy Breaker Tool.

Integration of the forward (student) canopy and the T-38 airframe and systems have been mechanically and economically considered. All TTC design work is documented by Space Ordnance Systems (SOS), a subcontractor to PPG Industries, Inc. The forward canopy was designed to satisfactorily pass the bird strike requirement, providing no structural failure occurs which prevents continued safe flight, spall segments larger than 0.250 cubic inches ejected towards the pilot, a puncture of the transparency which results in a hole larger than 1 square inch or a fracture pattern which would not resist a 4.0 pound secondary impact at a velocity of 130 knots. If any bird debris enters the cockpit area because of a temporary separation of the transparency and its supporting framework or between the framework of two transparencies, such as the forward windshield and forward (student) canopy, the remains will be of such quantity, direction, and nature to preclude injury to the

pilot which would prevent continuation of flight duties. Included in this study are Half-scale canopy fabrication process and production procedures.

2.0 FORWARD CANOPY

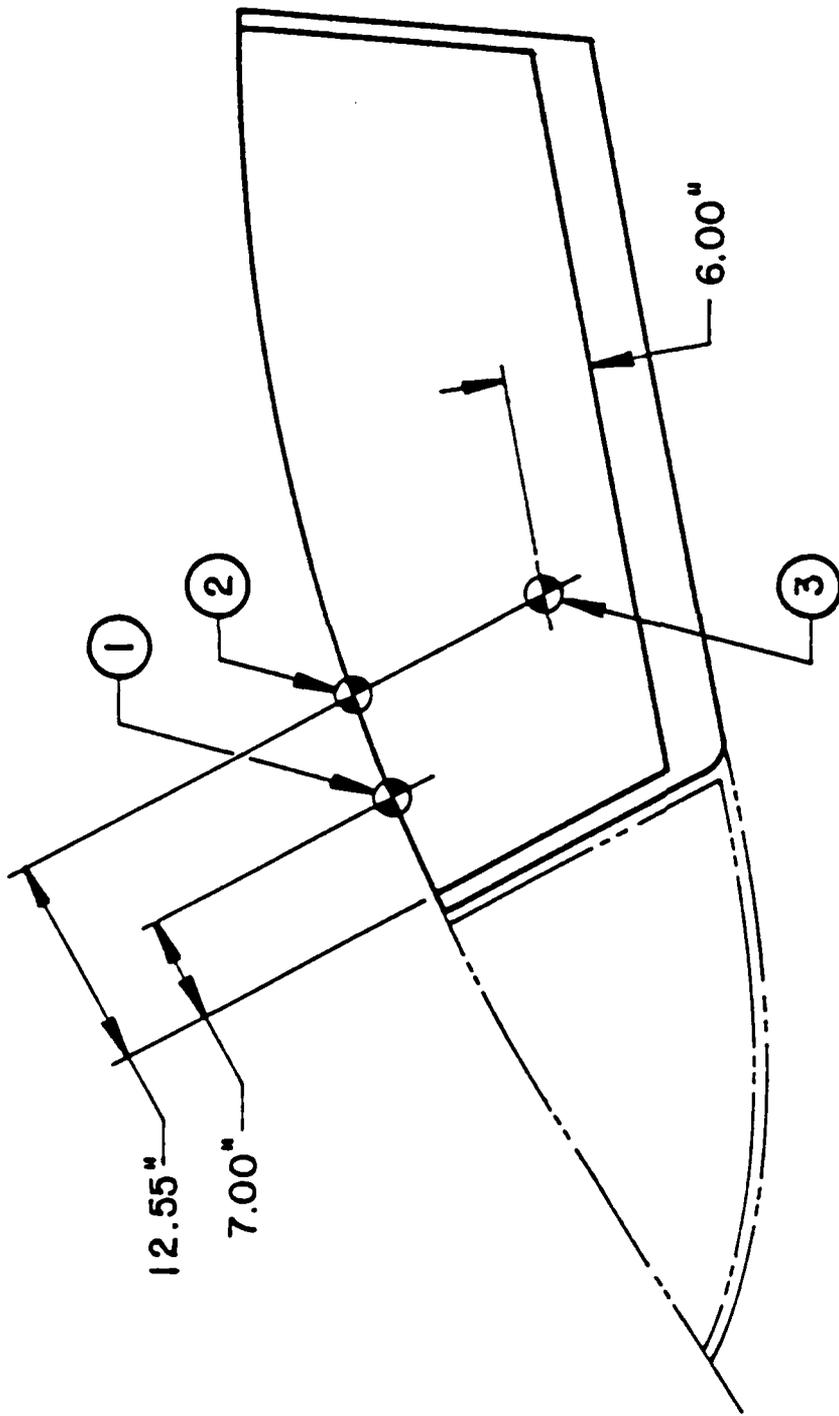
2.1 Statement of the Problem

The forward canopy poses a most difficult general problem of integrating thru-the-canopy (TTC) ejection system with improved bird strike resistance while maintaining present optical and durability characteristics. Combining efficient bird strike protection and TTC ejection are novel and contradictory requirements since the tough materials which resist bird penetrations also resist "punch through" ejection.

Specific problems fall into two areas for the forward canopy, those involving the transparency system (including support structure and TTC hardware interface), and those involving the TTC system itself. This section addresses the former, while the latter is covered here and in the Space Ordnance Systems (SOS) final report which has been included intact at the end of this section for clarity and ease of evaluation. PPG INDUSTRIES, INC. selected SOS as the subcontractor for TTC system development, evaluation and system recommendations.

2.1.1 Canopy System Bird Impact Resistance

As with the student windshield, the basic problem becomes a tradeoff of transparency bird protection versus weight. The thickness of the polycarbonate core in the recommended laminate of 0.125 inch cast acrylic - 0.050 inch I/L-0.350 inch polycarbonate or 0.400 inch monolithic polycarbonate may prove to be marginal. The University of Dayton Research Institute (UDRI) study shows 0.39 inch polycarbonate would be required for 400 knot penetration velocity (50 percent failure). Bird impact test location points are shown in Figure 1.



NOTES: (1) IMPACT POINTS 1 AND 2 ON FUSELAGE CENTERLINE.

(2) ALL DIMENSIONS IN INCHES, AS MEASURED ALONG TRANSPARENCY SURFACE.

FIGURE 1 - FORWARD CANOPY BIRD IMPACT LOCATIONS

In addition, although F-16 canopy data is reflected in the UDRI study, wave reflection as in the F-16 may require even thicker polycarbonate than predicted (Additive tensile waves may have been an aspect in the low 125 knot capability in the transition zone aft of the present forward edge, Figure 11 of the UDRI study).

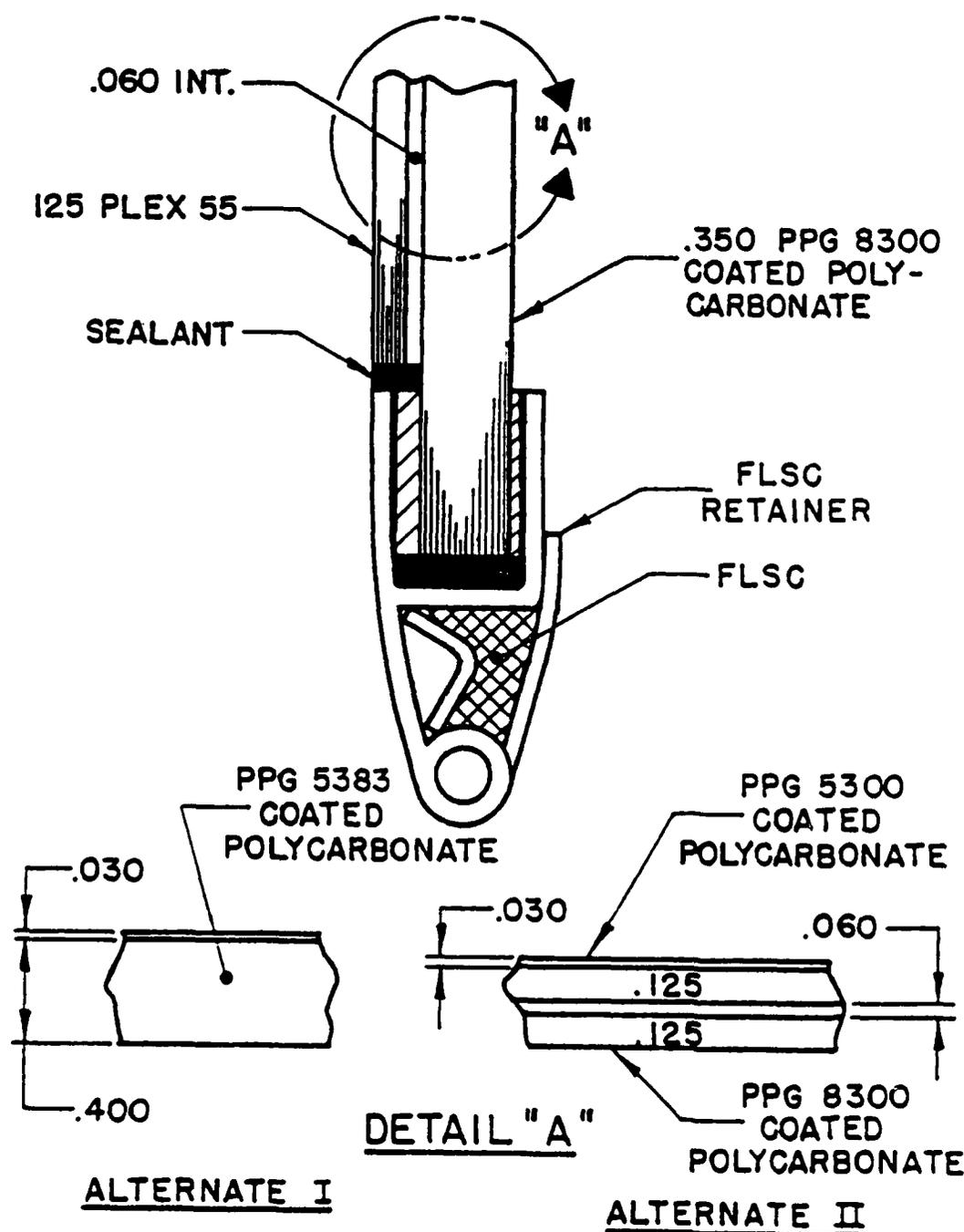
Beside the transparent portion itself, the edge members of the canopy can be expected to cause problems during impact. For example, more fixity may be required along the forward edge to prevent pullout or shearing of the transparency. Integration of the TTC ejection with edge impact was considered in developing the concepts discussed in the SOS report. By keeping the actuation system at the pins or containing the Linear Shaped Charges (LSC's) along the edges, problems should be minimized.

2.1.2 Canopy and TTC System Weight

Any significant canopy thickness increase will probably lead to a larger weight penalty than the total 25-pound goal. For example, the laminated 0.125 inch cast acrylic - 0.050 inch I/L-0.350 inch polycarbonate recommended in the UDRI study, would weigh approximately 40-45 pounds more because of extra material alone than the present 0.23 inch thick transparency. So again, it will be advantageous to minimize parasitic weight. A monolithic 0.400 inch polycarbonate cross-section would be borderline for bird protection yet the 0.170 inch thickness

increase would add approximately 20-24 pounds to the system. Such a canopy would also be borderline for durability, so a cross-section with 0.030 inch PPG 5300 liner over the polycarbonate outboard would be considered. It would weigh only 2-3 pounds more than the coated monolithic canopy, for a total increase of 22-27 pounds. A minimum weight alternate which PPG INDUSTRIES feels confident would meet the bird protection, would rely on a laminated core of two 0.125 inch polycarbonate plies with a 0.060 inch interlayer and faced with a 0.030 inch PPG 5300 liner outboard and abrasion resistant coating inboard. This type canopy would add approximately 15 pounds to the total weight. This "minimum weight" candidate would allow room for TTC hardware, yet stay as close as possible to the 25-pound target of structural additions. It would, however, create more optical and deflection problems than the monolithic design. Edge sections of the baseline recommended acrylic-polycarbonate laminate, liner faced monolithic alternate and minimum weight liner faced laminate appear in Figure 2.

Besides transparency thickness effects, the TTC ejection system will introduce extra weight to the total system. The problem with this facet will be to minimize the increment weight because of the added TTC components and canopy/TTC interface. This was a consideration by SOS developing the candidates in the Subcontractor's Report. The Pin Puller and Sill Cutting concepts introduced will add the following weights to the total system:



**FIGURE 2 - FORWARD CANOPY
CROSS SECTIONS**

Pin Puller: 4.2 pounds to system + 1.7 pounds canopy = 5.9 pounds total.

Sill Cutter: 2.7 pounds to system + 0.4 pound to canopy = 3.1 pounds total.

2.2 Problem Attack

2.2.1 TTC Concept Selection

The initial phase of the Forward Canopy study for the TTC system included canopy cross section. This was a critical aspect in total weight and portion of the effort was directed toward transparency processing.

Screening and ranking of the TTC systems for T-38 application was conducted by Space Ordnance Systems.

2.2.1.1 Establish TTC ranking criteria

PPG and SOS studied the compatibility with T-38 airframe and systems, bird strike resistance, post-bird strike function, structural, optical, injury potential (ground and air crew), maintainability, durability, integration with canopy process, use in monolithic or laminated canopy, edge member compatibility, and weight.

The three transparency cross sections (Figure 2) were considered by SOS in the TTC systems.

SOS evaluated "Reference C" report on "Reduction of Pre-Ejection Time Delay" (McDonnell Aircraft Company, MDCA 7127 and MDCA 7415 Reports). Selecting concepts which meet T-38 compatibility criteria.

These concepts were compared and reviewed in descriptions to include system details, previous experience and applicability as suggested by screening criteria rank.

Final Recommendations in the SOS report include: Primary and alternate TTC system for detail design, discussion of other concepts not in Reference C, and comments for transparency compatibility (See the Appendix, Subcontractor's Report).

3.0 T-38 FORWARD CANOPY FABRICATION PROCESS

The forward canopy fabrication process was used for one half scale preforming and vacuum forming trials. Some modification of the reforming and vacuum forming cycles will be necessary when scaling to full size. This effort showed that the proposed forming technique can yield acceptable surface quality, reduced edge distortion and contour control.

3.1 T-38 Forward Canopy Fabrication Procedure

The T-38 canopy fabrication procedure consists of initially pre-forming the polycarbonate ply to a simple semi-cylinder shape on a rotating pre-form skeleton iron, then vacuum forming the performed polycarbonate to its final shape in the vacuum forming tool. Prior to pre-forming the 5300 liner faced polycarbonate blank, a room temperature curing silicone elastomer, Sylgard 184, is cast to the 5300 liner surface to a thickness of 0.100 inch. The silicone intermediary eliminates surface burn and mark-off to the 5300 liner when it is in contact with the vacuum tool surface. The Sylgard 184 coated polycarbonate blank to be pre-formed is clamped to the pre-form tool (Figure 3) in a vertical position. Aluminum clamp with pre-forming weights attached is attached to the bottom edge of the polycarbonate. The polycarbonate sheet is then heated to 305 - 310°F, with a 60-minute hold time. The skeleton iron is then rotated causing the heated polycarbonate to conform to its shape (Figure 4). The pre-formed polycarbonate (Figure 5) is then fitted to the vacuum forming fixture (Figure 6) which was previously prepared with a peripheral band of Presstite sealant to create the vacuum seal to final form, the polycarbonate. The vacuum tool surface is also sprayed with a silicone lubricant to ease the vacuum forming operation. The pre-formed polycarbonate is then securely

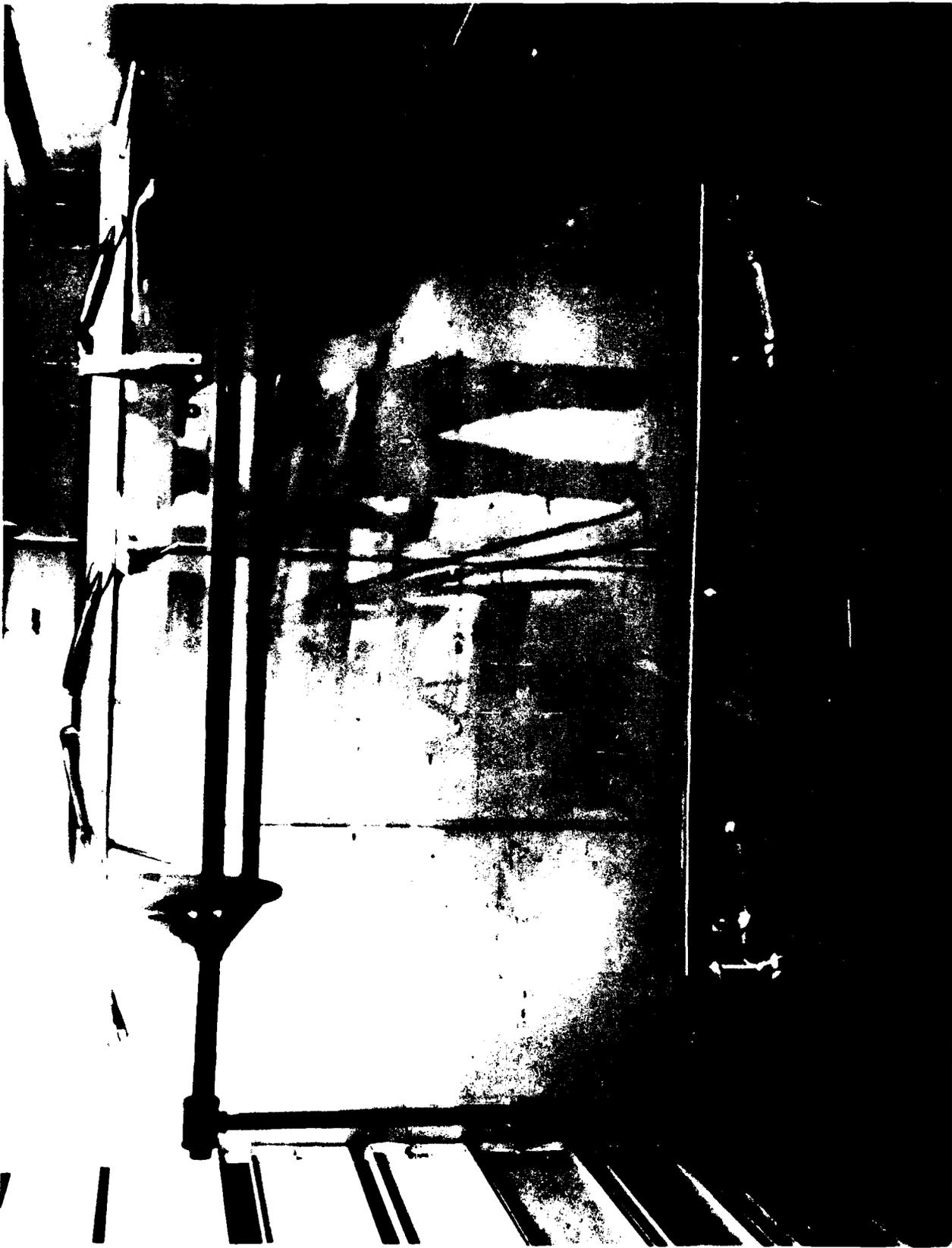


FIGURE 3
CANOPY PRE-FORM TOOL
WITH ATTACHED POLYCARBONATE



FIGURE 4
POLYCARBONATE PRE-FORMED
ON FORMING TOOL



FIGURE 5
PRE-FORMED POLYCARBONATE CANOPY



FIGURE 6
SUBSCALE CANOPY
VACUUM FORMING FIXTURE

clamped at the vacuum tools periphery (Figure 7) using aluminum plates and arches underneath the clamps. The assembly is then heated in an air circulating oven at 305°F for approximately 90 minutes. Five to eight inches of vacuum pressure is applied to the forming tool causing the heat softened polycarbonate to form to shape. The assembly is quickly cooled and the formed canopy removed from the vacuum forming tool (Figure 8).

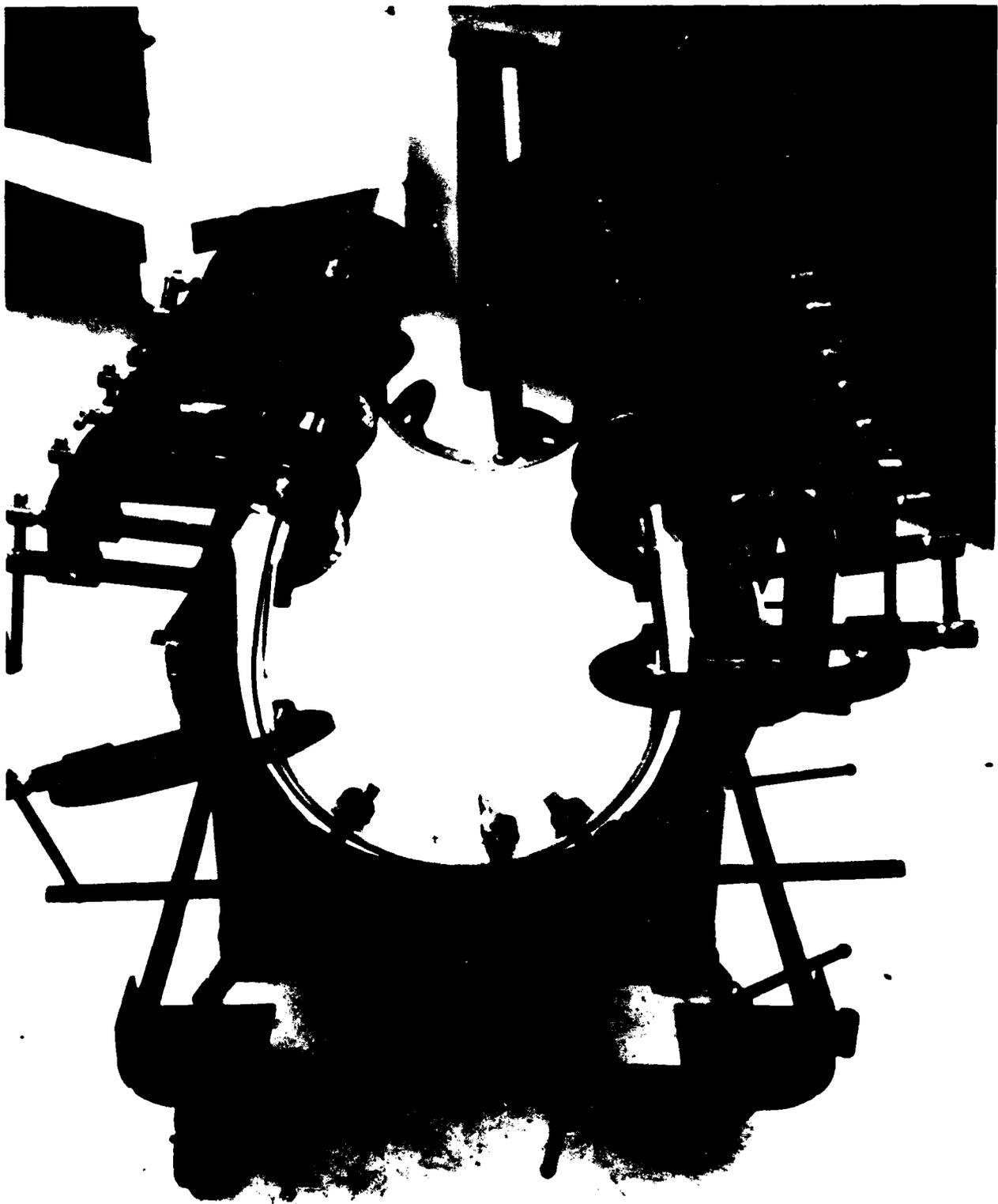


FIGURE 7
PRE-FORMED POLYCARBONATE
CLAMPED IN FORMING FIXTURE



FIGURE 8
FORMED CANOPY

3.2 Chemically Tempered Glass Pressing Plate Preparation

3.2.1 Material and Equipment Required

1. Two 0.250 inch x 48 inch x 72 inch optically good, chemically tempered pressing plates
2. Handling table
3. RX-3 release coating (Rainex plus 3 percent mold wiz)
4. Kay Dry's
5. Distilled water
6. Pumice
7. Rubber gloves
8. Safety glasses
9. Ultraviolet light source

3.2.2 Procedure

1. Inspect glass for defects and optical quality prior to and after chemical tempering.
2. The fire-polished surface of each pressing plate should be identified via UV light source (tin side is hazy).
3. Thoroughly clean the fire polished surface with pumice and water.
4. For new plates, two coats of RX-3 release coating are then applied to the cleaned, horizontal surface. RX is the abbreviation for Rainex which is a commercially available release material. The -3 stands for 3 percent mold wiz which is also commercially available. The first RX-3 coat is applied with full coverage using Kay Dry's and a wiping motion. When a dried haze is seen on the surface, a second coat is applied in a similar manner and allowed to dry. The RX-3 haze is removed by wiping with a dry cloth, then with Kay Dry's

and distilled water, the surface must be closely examined to determine 100 percent haze removal. The pressing plate is now ready for use.

5. For previously used plates, only a single additional RX-3 application is necessary prior to each subsequent pressing. The pressing plate surface and edges should also be inspected for damage prior to use.

Safety Note:

Wear rubber gloves and eye protection when handling and applying RX-3.

3.3 Polycarbonate Blank Preparation

3.3.1 Material and Equipment Required

1. VM&P Naphtha
2. Kay Dry's
3. 50:50 isopropanol (IPA) and water solution
4. TEDLAR
5. 3M Y-8403 tape - "green tape"
6. Rubber gloves
7. One 0.250 inch x 47-1/2 inch x 71-1/2 inch rectangular ply of aircraft grade polycarbonate

3.3.2 Procedure

1. Wear rubber gloves during all polycarbonate preparation and assembly steps.
2. Remove masking from one polycarbonate ply and place on a none marring table and examine for usability.
3. If the polycarbonate was protected with an adhesive backed paper that leaves a residue, a fast wipe with naphtha using a soft

non-marking cloth followed by a 50:50 IPA:H₂O solution wipe is usually sufficient for Cleaning. Inspect and repeat as necessary. If a non-adhesive backed paper is removed, a 50:50 IPA:H₂O solution wipe is all that is necessary. Mask temporarily with Tedlar using green tape.

4. Transport polycarbonate ply to oven area.
5. Carry into oven and attach to ceiling hangers. Check for positive engagement.
6. Oven dry polycarbonate plies at 225°F for a minimum of 16 hours.
7. Cool with air circulation in the oven (doors open) to approximately 125°F.
8. Immediately return the dried polycarbonate to a conditioned room.

3.4 Press Polishing Polycarbonate

3.4.1 Material and Equipment Required

1. Tedlar
2. 3M Y-8403 tape (green tape)
3. Distilled water
4. Non-woven fabric
5. 0.125 inch x 0.600 inch red silicone rubber strips
6. 3 inch Kraft acetate paper
7. No. 2 "A" clamps
8. Two 60 inch x 94 inch polymer bags
9. Two 0.063 inch x 48 inch x 72 inch aluminum sheets
10. Two 0.250 inch x 48 inch x 72 inch release coated, chemically tempered glass pressing plates

11. One 0.250 inch x 47-1/2 inch x 71-1/2 inch polycarbonate

3.4.2 Assembly Procedure

1. One surface of one sheet of 0.063 inch x 48 inch x 72 inch aluminum is covered with Tedlar which is trimmed to within 0.5 inch of the aluminum edges and taped in place with green tape. The aluminum is then placed on an assembly table with the Tedlar covered face down.
2. Three plies of non-woven fabric are then placed on the uncovered aluminum surface and trimmed to the aluminum sheet size.
3. One glass pressing plate is then placed on the non-woven fabric with the release coated surface up. The release surface should be checked for cleanliness and recleaned with distilled water if necessary. If recleaned, the glass should be allowed to dry for 20 minutes prior to polycarbonate placement.

Safety Note:

Wear plastic type gloves during all polycarbonate and glass assembly steps.

4. Concurrent with Step 3, the ply of 0.250 inch x 47-1/2 inch x 71-1/2 inch polycarbonate should be inspected for cleanliness and cleaned with 100 percent distilled water if recleaned, the polycarbonate should be allowed to air dry for 20 minutes prior to placement on the glass pressing plate.
5. Once cleaned and dried, the polycarbonate ply is placed onto the glass surface. The polycarbonate is approximately 1/2 inch smaller in length and width than the glass,

and a 1/4 inch space should be allowed along all four edges on the glass surfaces before clamping with No. 2 "A" clamps.

6. The second cleaned and release coated glass pressing plate is then placed on the ply of polycarbonate with the release coating in contact with the polycarbonate surface and is matched to the first glass pressing plate.
7. Repeat Step 1.
8. Place three plies of non-woven fabric on the glass pressing plate surface and trim to size.
9. Place the aluminum sheet on the non-woven fabric and match to the glass pressing plate,
10. The resultant 0.250 inch gap along each edge must be filled with red silicone rubber. The edge fill must completely fill the void and may slightly exceed the glass edges. With the fill in place, the assembly is clamped, then taped tightly together with 4 inch long pieces of Y4803 tape at 6 inch intervals. The clamps are then removed.
11. Tape a double layer of 4 inch Kraft acetate paper to the periphery of the assembly.
12. Make small razor cuts through the Kraft acetate and the Tedlar film on the aluminum to allow for air removal during the polymer bagging operation.
13. Tape a ply of 0.125 inch x 4 inch silicone rubber cut 0.250 inch wider than the thickness of the assembly at each corner of the panel to keep the aluminum corners from puncturing the polymer bag.

3.4.3 Polymer Bagging Procedure

1. Place assembly in polymer bag.
2. Evacuate the first bag for 15 minutes before sealing. Evaluate the second bag for 5 minutes prior to sealing.

3.4.4 Autoclave Press Polishing Cycle

1. Polycarbonate-21 cycle
 - a. Heat on during pressurization to 200 psi
 - b. Heat to 330°F.
 - c. Hold at 330°F for 60 minutes.
 - d. Cool to 100°F at maximum rate.
 - e. Continue cooling for 30 minutes.
 - f. Blow down.

3.4.5 Post Press Polish Stripping

1. Place assembly on suitable table. Cut and remove polymer bag.
2. Remove the Y4803 tape holding the assembly together.
3. Lift off the 0.063 inch aluminum plate.
4. The top glass plate is removed by gently prying it with a wedge-shaped piece of plastic. The wedge-shaped piece of plastic is placed between the glass and the polycarbonate and a gentle wedging motion is used to pry the glass from the polycarbonate. If the glass and polycarbonate are tightly bonded together, it may be necessary to gently tap the wedge with a wooden mallet.
5. Remove the glass ply and store.
6. Release polycarbonate from the bottom glass ply as in Step 4.

7. Lift polycarbonate from assembly and place on rack. When handling polycarbonate plastic, throw away gloves should be used to eliminate the possibility of finger prints on the polycarbonate surface.
8. Remove bottom glass ply and store.
9. Remove aluminum sheet and store.
10. Inspect polycarbonate for usability. In addition to determining acceptability, identify the better optics end as the forward arch.

3.5 Dow Corning Sylgard 184 Application

3.5.1 Material and Equipment Required

1. Sylgard 184 encapsulating resin and curing agent
2. Desiccating mixing vessel
3. Compressed air source
4. Vacuum supply
5. Spatula
6. Freezer
7. 0.125 inch x 0.250 inch 3M PUR foam tape
8. Dow Corning 1200 primer and mohair swabs
9. 50:50 IPA:H₂O mix

3.5.2 Sylgard 184 Preparation Procedure

1. Weight out sufficient Sylgard 184 with curing agent to cast a 0.100 inch layer on the polycarbonate surface and pour into desiccator. Mix together using spatula for approximately 3-4 minutes.
2. Place lid on the vacuum chamber containing the Sylgard mix and use 28 inches of vacuum pressure to remove the entrapped air. Bubbles

will form and they should be collapsed by briefly disconnecting the vacuum hose and introducing atmospheric pressure. The vacuum operation should continue for 5-10 minutes or until most of the bubbles have disappeared.

3. The degassed material can be stored in a 0°F freezer for up to 5 days.

3.5.3 Polycarbonate Blank Preparation

1. A ply of chemically tempered glass, the same size as the polycarbonate blank is placed on a work table in a clean room. The glass surface is covered with two plies of non-woven fabric. The polycarbonate is placed on the non-woven fabric and the assembly is leveled by shimmying where necessary.
2. Clean polycarbonate if necessary using 50:50 IPA:H₂O mix.
3. A dam of 0.125 inch thick x .240 inch wide foam tape is placed on the perimeter of the polycarbonate. A second dam is applied 2-3 inches in from the first dam along the long and short sides. The second dam is needed to stop clamping cracks from propagating across the Sylgard surface.
4. A light coat of Dow Corning 1200 primer is applied with a clean mohair swab to the area between the two dams and to a 1 inch peripheral band next to the inner. Primer drying time is 60 minutes in a conditioned dry room.

5. The degassed Sylgard mix is poured onto the central area of the polycarbonate sheet. If the Sylgard has been frozen, it should be placed in a 70°F room for 40 minutes prior to pouring. The Sylgard will naturally flow over the polycarbonate surface. A spatula is usually necessary to spread the Sylgard to the edges and corners. The casting and spreading operation will cause small bubbles to form in the Sylgard mix. These can be removed by blowing a light stream of compressed air on the bubbles. The bubbles should be allowed 15 minutes to rise to the surface before removal is attempted.
6. The Sylgard will level out and gel in approximately 16 hours at 66-70°F.
7. The gelled Sylgard must be post cured in an oven that has been pre-heated at 117°F for 30 minutes. After quickly placing the table in the oven, the Sylgard is cured for 2 hours with the heating elements and fan off. Return panel to conditioned room.

3.6 Canopy Preforming Procedure

3.6.1 Materials and Equipment Required

1. Sylgard coated polycarbonate blank with center lines identified on short sides
2. Preform skeleton iron
3. "C" clamps
4. Three pieces of aluminum 0.250 inch x 2 inch by the width of the polycarbonate
5. Lead forming weights
6. Temperature recorder with thermocouple
7. Protective clothing

8. MSA top guard cool air hats and breathable air supply

3.6.2 Procedure

1. Attach skeleton preform iron to rotating axle in hot air oven.
2. Position polycarbonate vertically with one long edge against the sill bar of the preforming tool. Place a 0.250 inch x 2 inch piece of aluminum cut the same length as the polycarbonate width on the polycarbonate edge directly opposite the sill bar and clamp in place.
3. Place two pieces of 0.250 inch x 2 inch aluminum cut the same length as the polycarbonate on opposite sides of the lower polycarbonate edge and clamp together.
4. Attach one 10 pound lead forming weight on each end of the lower aluminum bars.
5. Spot thermocouple on the inboard and outboard polycarbonate surfaces near the edge and position a third thermocouple to monitor oven air temperature.
6. Heat oven to 305-308°F and soak polycarbonate for 90 minutes.
7. Slowly rotate the preform tool. This will cause the polycarbonate to conform to the shape of the preform tool.
8. Quickly cool the formed polycarbonate.
9. When cool enough to handle, remove the two lead weights.
10. Rotate the forming tool so that the sill areas face the oven ceiling.

11. Remove all clamps and carefully pull the formed polycarbonate from the forming tool.
12. Store formed polycarbonate in a conditioned dry room until ready to vacuum form.

3.7 Vacuum Tool Clean-Up and Side Extension Sealing

3.7.1 Material and Equipment Required

1. Vacuum tool with side extension removed
2. Aluminum clamping bars and arch rings
3. Razor blade scrapers
4. Naphtha
5. 3M Y-8403 tape
6. Dem-Cote Lubricant 2X988-A (one aerosol can)
7. Presstite Sealant
8. G.E. RTV 108 silicone sealant or equivalent
9. "C" clamps
10. Respirator

3.7.2 Procedure

1. Cured G.E. 108 silicone sealant, which is used to seal the side extension to the vacuum tool, must be removed from the wing and tool mating surfaces using razor blade scrapers. The mating surfaces and tool cavity are then cleaned with a naphtha wipe and inspected.
2. Y-8403 tape (1 inch wide) is placed just inboard of the bolt holes on the cavity side extension bonding surface. The side extension bonding surface and the main cavity wing extension bonding surface are sprayed with Dem-Cote lubricant 2X988A.

Safety Note:

Spray Dem-Cote in a well ventilated area. Operator must wear respirator to avoid inhalation of propellant.

The Y-8403 tape is removed and replaced with a 3/16 inch bead of G.E. 108 RTV sealant. The side extension is then fitted to the bead covered cavity bonding surface and bolted in position. The edge is then tightly clamped together using "C" clamps.

3. G.E. 108 RTV sealant depends on moisture for curing. If the wing sealing occurs on a dry day, moist towels should be placed along the bonding surface to assure curing. During the clamping operation in Step 2, excess G.E. 108 may extrude and cure along the mating line in the tool cavity. This material should be carefully cut off with a sharp razor blade.
4. Clean the vacuum tool cavity using naphtha and paper towels.
5. Apply a 2 inch band of Y-8403 tape to the periphery of the arches and side extensions for later Presstite application.
6. Spray the cavity liberally with a coating of Dem-Cote lubricant 2X998-A.
7. Remove 2 inch of Y-8403 tape from the periphery of the arches and side extensions.
8. Protect Dem-Cote sprayed cavity with tedlar cover until ready to insert polycarbonate preform.
9. Clean the contacting surfaces of the aluminum clamping bars using naphtha. Apply a light

spray of Dem-Cote 2X998-A to the entire contacting surface of the clamping bars.

Safety Note:

Spray Dem-Cote in a well ventilated area. Operator must wear respirator to avoid inhalation of propellant.

3.8 Preform Insertion, Clamping, and Instrumentation

3.8.1 Materials and Equipment Required

1. Prepared vacuum tool (Section XI)
2. Aluminum arch ring and side bars
3. Preformed polycarbonate (Section X)
4. Presstite sealant
5. Temperature recorder with thermocouple
6. "C" clamps

3.8.2 Installation of Preform into Vacuum Fixture

1. Two adjacent strips of Presstite sealant are applied parallel to the forward and aft arch areas and along the top edges of the vacuum forming tool. Remove the protective paper backing from the Presstite sealant.
2. The polycarbonate preform is held above the vacuum forming tool and while pushing the sill areas toward each other, is lowered slowly into the tool and the previously identified polycarbonate arch centers are matched to the center mark on both arches of the vacuum forming tool. Temporarily clamp polycarbonate in this position.

3.8.3 Clamping Arch Rings and Side Bars

1. The temporary clamp is removed from the

forward arch and the forward arch hold-down ring is clamped in place using "C" clamps. The center area is clamped first to maintain the preform position in the vacuum tool. The same procedure is used for the aft arch hold-down ring.

2. One aluminum sill bar is placed on the inner side of the polycarbonate preform approximately even with the top edge of the vacuum tool and clamped tightly at the sill bar ends. "C" clamps are placed approximately 4 inches apart between the end clamps. The two end "C" clamps on either end of the sill bar should be securely tightened while the remaining clamps are to be sufficiently tightened to maintain a vacuum seal but should be loose enough to allow the polycarbonate to slip between the forming tool and sill bar during vacuum forming.

3.8.4 Thermocouple Application

1. Six thermocouples are used for the vacuum forming effort and are attached with aluminum foil tape as follows:
 - No. 1. Bonded to the polycarbonate at the forward arch center.
 - No. 2. Suspended approximately 4 inches above No. 1.
 - No. 3. Bonded to the polycarbonate at the aft arch center.
 - No. 4. Suspended approximately 4 inches above No. 3.
 - No. 5. Bond to the center of left side sill bar.

No. 6. Bond to the center of right side sill bar.

3.9 Final Forming

3.9.1 Materials and Equipment Required

1. Polycarbonate preform in vacuum tool
2. Vacuum pump
3. Protective clothing
4. MSA top guard cool air hats with breathable air supply
5. Liberty smoke sticks - Model 15-049
6. Multi-point temperature recorder

3.9.2 Vacuum Forming

1. Push the vacuum tool into the oven aft arch first. The tool should be oriented for best viewing from the oven windows.
2. Attach the line from the vacuum pump to the tool. Turn on the pump and set vacuum pressure to 4 inches HG. If there is not a good agreement between the vacuum tool cavity gauge and the pump gauge, check for leaks. This can be done by listening or with smoke sticks. Minor leaks can usually be corrected by adjusting clamping or sealing with additional Presstite sealant. Turn off vacuum pump when leak is sealed.
3. Close the oven door and set the temperature control to 250°F. Since the presoak is usually overnight, set the timer to start the cycle 5 hours before the forming shift.

Note:

Polycarbonate vacuum forming is influenced by residual stress, Sylgard casting techniques, and tool preparation. Therefore, the times,

temperatures, and pressures listed should only serve as a general guide.

Safety Note:

Operators may be required to enter the heated oven during the vacuum forming process. Contact with hot equipment by insufficiently protected skin will cause burns. Breathing forming temperature air can damage the respiratory system. Therefore, wear protective suits, gloves, and MSA top guard cool air hats connected to a breathable air supply.

4. Check clamps and re-slug if necessary. Increase the oven temperature control setting from 250°F to 305°F.
5. When thermocouple No. 1 and No. 3 read 300°F, continue soaking for up to 90 minutes.
6. Turn on vacuum pump and control to 5 inches HG. The polycarbonate will start drawing into the tool cavity via edge seepage. Monitor the sides for equivalent slip rates and re-adjust clamps when necessary.
7. An increase in vacuum pressure will indicate that the canopy is formed. Visually check to confirm complete forming.
8. Reduce oven control to 100°F and open oven doors to cool the formed canopy. Maintain vacuum pressure until thermocouple No. 1 and No. 2 read approximately 230°F. Move vacuum tool with formed canopy out of the oven. Reduce vacuum and visually monitor to insure that the part remains in contact with the tool. If not, restore vacuum pressure. Repeat until blank is formed, then disconnect the vacuum pump and cool the assembly.

9. When the formed canopy and vacuum tool have cooled to a temperature suitable for safe handling, remove the forward and aft arch clamps and rings.
10. Remove clamps and aluminum side bars from the sill area of the canopy.
11. Unbolt the vacuum tool side extension and remove.
12. Press the canopy sill areas away from the vacuum tool surface to break the Presstite vacuum seal and gently lift the canopy from the vacuum tool cavity.
13. Invert the canopy so that it rests on its sill edges on a clean flat top.
14. Replace vacuum tool side extension, bolt together for final cool-down.
15. Remove Sylgard intermediary and discard.
16. Perform cursory grid board and point source inspections.
17. Apply Spraylat TR-6683 peelable coating to both surfaces of the polycarbonate blank using electra-air spray gun. Spray with slow vertical strokes giving each surface 3 to 4 coats.
18. Place Spraylat coated polycarbonate in a 130°F air circulating oven until Spraylat is thoroughly dry.
19. Send to finishing department for final trim and finishing.

APPENDIX

SUBCONTRACTOR'S REPORT

SPACE ORDNANCE SYSTEMS

PPG-CDRL-6

ALTERNATIVE TRANSPARENCIES FOR IMPROVED BIRD STRIKE PROTECTION

T-38 Clear Path Egress System

Stan Phillips
Space Ordnance Systems
25977 Sand Canyon Rd.
Canyon Country, California 91351

April 29, 1982

Final Report, Technology Assessment, Concept Review and Concept Selection

Prepared For:

PPG Industries
Works 23
Creighton, Pennsylvania 15030

AIR FORCE FLIGHT DYNAMICS LABORATORY
Air Force Systems Command
Wright-Patterson Air Force Base, Ohio 45433



SUMMARY

This Final Report provides two alternative Through The Canopy (TTC) Egress Systems for the T-38 Aircraft Bird Strike Resistant Canopy. The Bird Strike Resistant requirements for the canopy mandates the transparency material be very tough and bird collision resistant. Combining efficient collision protection and TTC ejections are novel and contradictory requirements since the tough materials which resist bird penetrations also resist "punch through" ejections.

The present Primary Egress System for the T-38 Aircraft provides forward canopy jettison and seat ejections by automatic sequence or manual selection by the flight crew. Also, other features provided for by the present Primary System are Ground Crew Canopy Jettison and In-flight TTC Egress Mode. The later consists of a cutting blade mounted to the top of the flight crews seat.

The seat mounted cutting blade is virtually ineffective in cutting through materials which comply with Bird collision resistance. It is necessary before seat ejections that the canopy or large sections be removed to assure serious injury is not inflicted on the occupant of the forward canopy position.

Based on the above design, two alternative TTC Egress Systems were designed and studied to provide reliable forward canopy removal. A description of each alternative system follows:

A. Pin Pull System

This system uses Shielded Mild Detonating Cord (SMDC) on the Pin Puller to actuate the remove of the canopy, lock/latch pins and the canopy hinge pins. After releasing the canopy a SMDC actuator Thruster propels the canopy up and away from the cockpit.



SUMMARY (continued)

B. Sill Cutting System

This system uses a Flexible Linear Shaped Charge (FLSC) (chevron shaped) to cut the forward and aft former's and the canopy sill. After the canopy removal a SMDC actuator Thruster propels the canopy up and away from the cockpit.

Both of the above systems can be easily developed, integrated, qualified and produced without technical risk. To minimize cost and system space requirements, both proposed systems use the Primary Egress System. Therefore, all automatic sequence and crew selected egress modes of operation, are available to the TTC Egress System. No independent action is needed to initiate the functions of TTC System.

Each of the two systems provides canopy removal without severance of the canopy transparency. This important feature eliminates personnel injury from shattered transparency shrapnel.

A basic problem became a tradeoff of transparency bird protection versus weight. The affect of transparency thickness and the TTC ejections' system introduced extra weight to the total system. The problem with this facet was to minimize the increment because of added TTC components and weight associated with canopy/TTC interface. The total canopy and TTC System weight penalty of 25 pounds was closely adhered to. The "minimum weight" candidate for the canopy was approximately 15 pounds of total weight. This "minimum weight" candidate would allow room for TTC hardware and structural additions yet stay as close as possible to the 25 pound target. The Pin Puller and Sill Cutting systems added the following weights to the total system:



SPACE ORDNANCE SYSTEMS

SUMMARY (continued)

A. Pin Puller

4.2 pounds to system + 1.7 pounds to canopy = 5.9
pounds total.

B. Sill Cutter

2.7 pounds to system + 0.4 pound to canopy = 3.1
pounds total.



TABLE OF CONTENTS

<u>NO</u>	<u>DESCRIPTION</u>	<u>PAGE</u>
1.0	INTRODUCTION	1
2.0	REVIEW COMMENTS, REPORT C	2
3.0	ASSESSMENT OF TTC TECHNOLOGY	4
4.0	DESIGN CONCEPT REVIEW - INITIATION SYSTEMS	27
4.1	Gas Initiation Systems	33
4.2	Concept Number 5 - Cable Initiation-Bulkhead Mounted	58
4.3	Concept Number 6-Dual Cable Initiation-Canopy Mounted	64
5.0	REVIEW OF CANOPY SEVERANCE AND REMOVAL DESIGN CONCEPTS	69
5.1	Explosive Cord Configuration	71
5.2	Concept A Overhead Canopy Cut/Pusher	73
5.3	Concept B Parimeter Severance/Pusher	80
5.4	Concept C Parimeter Severance/Rocket Motors	84
5.5	Concept D Centerline Severance/Parting Structure	87
5.6	Concept E - Side and Rear FLSC Severance/Pusher	91
5.7	Concept F - Side and Rear Severance Using Edge Imbedded MDF/Pusher	93
6.0	CONCEPT EVALUATION	96
6.1	Evaluation	96
6.2	Rationale For Evaluation Criteria	97
6.3	Concept Evaluation Results	104



LIST OF ILLUSTRATIONS

Figure		Page
1	MDF Installation	7
2	MFD Performance with Acrylics	9
3	Edge Imbedded MFD	13
4	Typical Forward & Aft Edge Attach For Edge Imbedded MFD	16
5	FLSC Cutting Process	19
6	Takeoff Location For Ballistic Gas	28
7	Lanyard Control Cable Location	29
8	T-38 Crew Escape System Schematic	30
9	Gas Initiated System With Separate Initiators For Ground Egress	40
10	Gas/SMDC Initiator	41
11	Transfer Manifold Canopy Severance Charge	42
12	Transfer Manifold Installation	43
13	Ground Egress Initiator	44
14	Gas Initiated System - Bulkhead Mount Initiator With Lanyard Actuated Ground Egress	48
15	Initiator - Gas and Lanyard Actuated	49
16	Gas Initiated System - Canopy Mounted Initiator With Lanyard Actuated Ground Egress.....	53
17	Dual Gas Initiation With Cable Ground Egress	56
18	Gas Actuated Detonator	57
19	Cable Initiation - Bulkhead Mounted Initiator ...	59
20	Lanyard Attachment Hardware	60
21	Lanyard Operated Initiator Assembly	61
22	Four Way Input	62
23	Dual Cable Initiators - Canopy Mounted Initiators	65
24	Lanyard Detonator	66
25	Lanyard Detonator Canopy Frame Mount Transfer Manifold	67
26	Canopy Position With Aerodynamic Assistance	70



LIST OF ILLUSTRATIONS (continued)

27	FLSC Severance Charge	72
28	Panel Severance With Pusher	75
29	Position Of The Canopy At Catapult Strip Off	78
30	Perimeter Severance With Pusher	83
31	Perimeter Severance With Rocket Motors	86
32	Centerline Severance With Seat Mounted Parting Structure	89
33	Side And Rear FLSC Severance With Seat Mounted Pusher	92
34	Side And Rear Severance Using Edge Imbedded MDF With Seat Mounted Pusher	95



LIST OF TABLES

Table		Page
I	CKU-7 Catapult Performance Characteristics	79
II	Initiation Systems Concept Evaluation	100
III	Initiation Systems Concept Evaluation (continued)	101
IV	Severance And Canopy Removal Concept Evaluation .	102
V	Severance And Canopy Removal Concept Evaluation (continued)	103
VI	Initiation Systems Concept Evaluation Summary ...	104
VII	Severance And Canopy Removal Concept Evaluation Summary	105



SPACE ORDNANCE SYSTEMS

1.0 INTRODUCTION

This document is submitted in accordance with PPG Industries Purchase Order Number 1-7255, line items 3 and 4.

The data contained in MDC reports MDCA7127 and MDCA7415 presents a very thorough review of ejection and TTC system technology. Therefore, the SOS effort presented herein is directed toward implementation of present technology which could be applied to the T-38 program.

This document contains a brief assessment of current TTC technology and a review of potential T-38 Clear Path Egress systems which are compatible with the T-38 aircraft airframe and systems.

This report also includes the primary and alternate concepts selected by Space Ordnance Systems for the detail design phase of the program.



SPACE ORDNANCE SYSTEMS

2.0 REVIEW COMMENTS - REPORT C, MDAC NUMBER MDCA7415,
REDUCTION OF PRE-EJECTION TIME DELAY

2.1 T-38 Applicability

2.1.1 The major portion of Report C is not directly applicable to the T-38 Bird Strike Resistant Canopy Program. However, several of the concepts discussed in the report help to validate details and concepts proposed by Space Ordnance Systems for use on the T-38 Clear Path Egress System. Some examples of this are listed below.

- ° Ballistic rocket motors provide faster clearance of canopy for ejection than the pivot thruster technique.
- ° Seat Canopy pushing surface combined with overhead severance and hinged side sills provides safe, reliable ejection.
- ° Full perimeter severance of canopy with positive removal of severed transparency from the ejection path has considerable merit.

2.1.2 Potential T-38 Implementation

Configuration III, Figure 36 is an interesting approach which provides perimeter severance for ground egress and overhead severance for in flight egress. SOS is of the opinion that a variation of configuration III has merit for T-38 application consideration.

2.2 Air Crew Ground Egress

The MDAC report recommends concepts which should be studied in further detail to determine their potential implementation. All of the concepts provide for ground crew initiation of the canopy jettison feature, which is absolutely essential. However, none of the concepts proposed by MDAC include an air-crew initiated ground egress capability. SOS can only assume that this important feature was intentionally omitted or was inadvertently overlooked.

SPACE ORDNANCE SYSTEMS

3.0 ASSESSMENT OF TTC AND CLEAR PATH EGRESS SYSTEM TECHNOLOGY

3.1 System Requirements

With the T-38 application there are three basic functions which must be integrated to provide the overall system performance parameter of clearing the transparency from the ejection path. These functions are;

- System Initiation
- Canopy Transparency Severance
- Clearing The Ejection Or Escape Path

The above functions must be provided during in-flight ejection and for emergency ground egress. Each function is singularly unique, yet none of the functions is more important than the other. Nor is the in-flight mode more critical or important than the ground egress mode. The objective is to provide rapid, reliable escape in the event of an injury or life threatening situation while on the ground or in the air.

3.2 Initiation And Sequencing Components

Space Ordnance Systems has designed and developed crew escape system components for over 15 years. During this time SOS has manufactured components for ballistic gas systems, explosive systems and hybrid systems utilizing ballistic gas and explosive components. Section 4.0 of this document entitled "Design Concept Review" specifies components which are totally compatible with the T-38 application. The Design Concept Review section of this document summarizes the results of the SOS technology assessment by presenting several system concepts that can be utilized on the T-38 aircraft.

The major consideration in this phase of the program has been to modify existing components and functions for compatibility and integration into the existing T-38 system and airframe.

3.3 Canopy Severance Technology

3.3.1 Cast And Stretched Acrylic-Non Bird Resistant

Most technology to date for canopy severance has been associated with stretched and cast acrylic materials. The acrylic materials are easily cut and broken up into small sections.



3.3.1

Cast And Stretched Acrylic-Non Bird Resistant
(Continued)

This is due to the acrylic materials having a tendency to propogate cracks and fracture paths in a pre-determined pattern.

The acrylic non bird resistant materials are generally severed using mild detonating fuse of either round or rectangular cross section. The mild detonating fuse (MDF) is usually installed in an extruded rubber holding strip which is bonded to the internal canopy surface. The holding strip provides the required standoff air gap while also protecting the MDF from mechanical damage. A typical installation for MDF is shown on Figure 1.

When MDF is initiated the explosive decomposition instantaneously releases large quantities of gas under extreme pressure, as much as several million pounds per square inch. The shock wave produced by the expanding gases move outward radially and longitudinally, and generally conform to the cross sectional shape of the MDF. The shock wave emanating from the surface adjacent to the canopy material converge in a plane parallel to the cord axis and cause an extreme pressure concentration along the convergent plane.



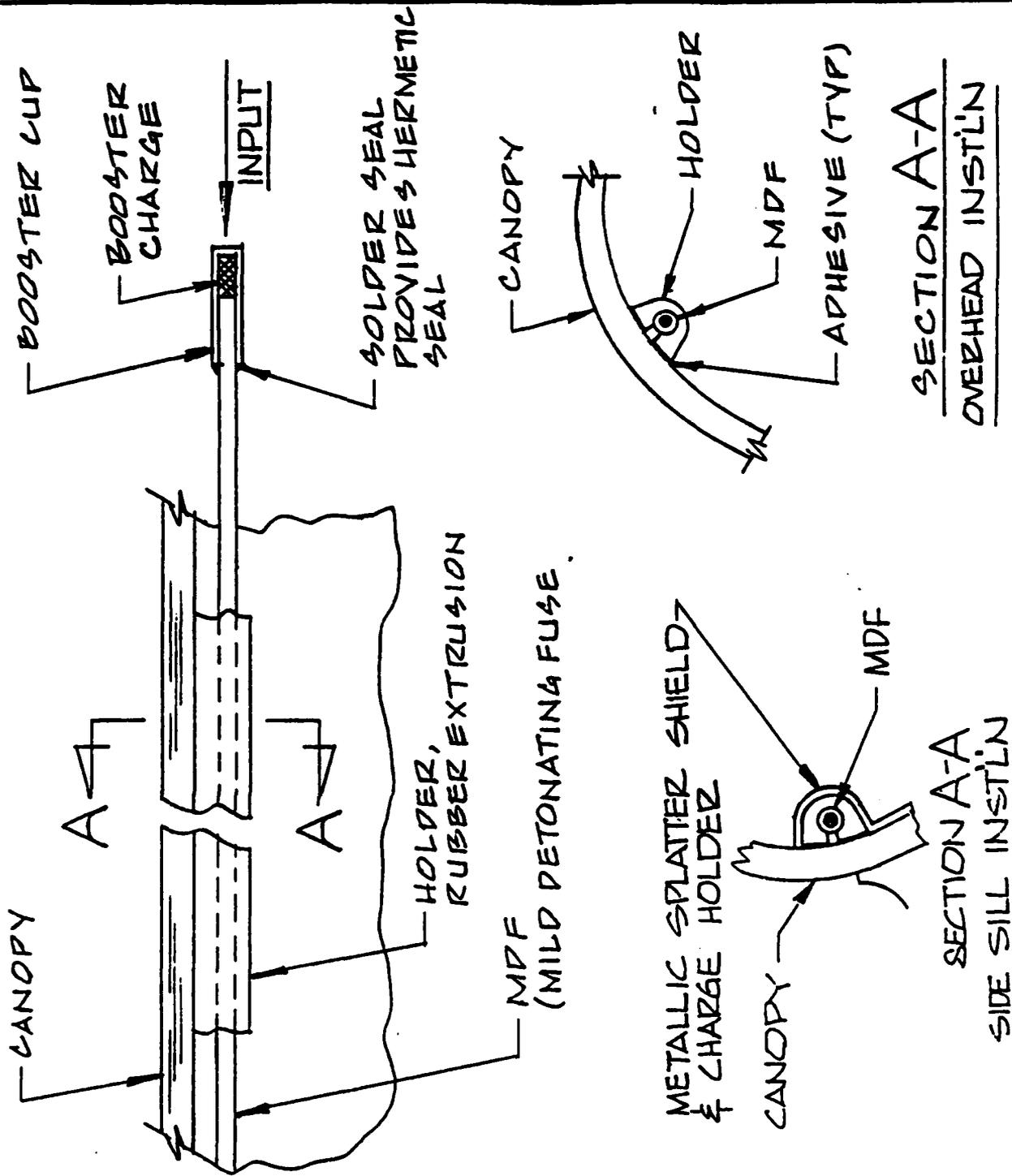


FIGURE 1
MDF INSTALLATION



3.3.1 Cast And Stretched Acrylic-Non Bird Resistant (Continued)

The result is a high energy shock wave directed at the target which literally fractures the material along the longitudinal axis of the MDF. Figure 2 illustrates the typical fracture and fragmentation features for each type of common MDF when detonated into acrylic canopy material.

Canopy Severance Patterns

Many variations of overhead patterns have been used for escape systems. A listing of the basic overhead patterns is given below, but it should be noted that many variations of these basic patterns have or could be implemented.

Single Overhead Centerline Cut

This pattern structurally degrades the canopy allowing the seat and pilot to be ejected through the remaining canopy structure. The result of this pattern is primary fracturing down the canopy centerline and secondary angular fracturing emanating from the primary fracture as a result of shock wave interaction within the material.



SPACE ORDNANCE SYSTEMS

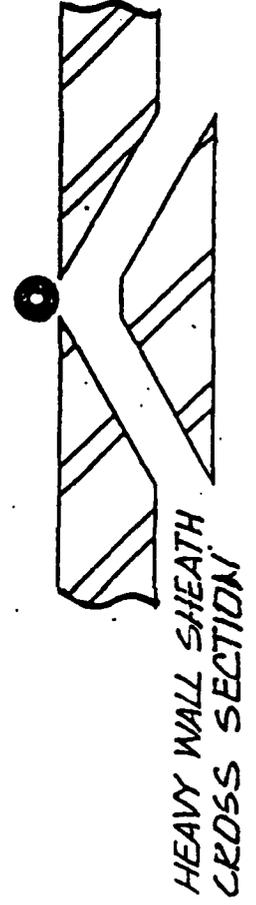
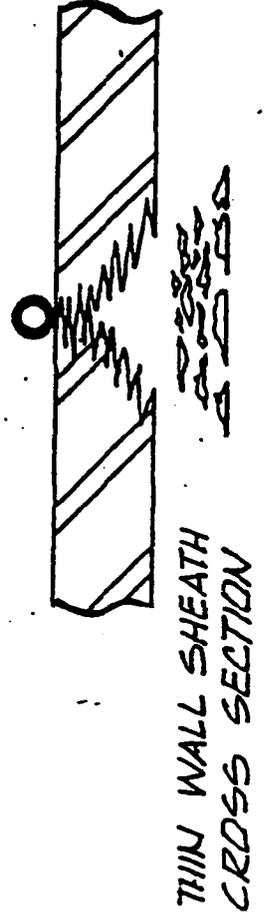
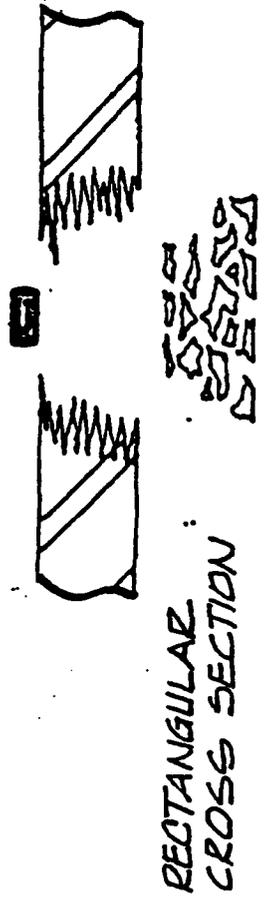


FIGURE 2
MDF PERFORMANCE WITH ACRYLICS



Overhead Panel Cutout

This pattern cuts a panel from canopy of sufficient size to allow seat and pilot ejection without contacting the canopy structure. Again the primary and secondary fracturing is introduced by shock wave interaction.

Full Perimeter Cut

This pattern utilizes a single loop of MDF running around the fuel perimeter of the canopy. The principle here is that the entire canopy can be severed basically in one piece except for those portions broken up by secondary fracture. This technique allows seat and pilot ejection without contacting the canopy or going through the canopy.

Overhead Sawtooth Cut

This pattern implements a loop of MDF incorporating sawtooth shaped crack initiation points. This pattern is intended to breakup the ejection envelope into sufficiently small fragments so that injury will not occur.



Overhead Sawtooth And Perimeter Cut

This pattern implements an overhead loop of MDF with sawtooth crack initiation points combined with a loop of MDF running around the full canopy perimeter. This concept provides total canopy breakup by utilizing primary crack initiation and propagation along with secondary fracture initiation and propagation caused by flexural wave systems within the canopy.

3.4 Polycarbonate And Laminated Combination-Bird Resistant

3.4.1 Severance With Mild Detonating Fuse (MDF)

With the advent of laminated and high strength monolithic materials for bird resistant applications a new technology has developed. These new materials and processes have created a new challenge in controlled severance for aircrew egress. Unlike the monolithic acrylics, the laminated designs and monolithic polycarbonate designs do not have a tendency for fracture initiation and propagation and are generally much more tenacious. For this reason, what works well for cutting the monolithic acrylics is virtually ineffective for cutting laminates and polycarbonates with bird impact resistance capability.



3.4.1 Severance With Mild Detonating Fuse (MDF)
(Continued)

Mild Detonating fuse can reliably sever the bird resistant materials, however, the penalty here is that the explosive core charge must be drastically increased, thus assuring a hearing impairment. As we discussed earlier the shock wave emanates radially outward from the MDF and therefore all of the shock wave front is not directed at the target. In fact the major portion is directed away from the target and into the rubber holding strip wherein a portion of the shock is re-directed back into the target. For this reason the bonded MDF and holder as shown on Figure 1 is quite inefficient and other techniques must be applied for the T-38 program.

The MDAC report suggests that MDF can be imbedded in a slot on the edge of the canopy and that predictable and reliable severance can be obtained. Refer to Figure 3 for illustrated installation and theoretical performance of this concept. Their analysis is correct and very timely. This concept utilizes a sweeping detonation technique wherein at the time a shock front reaches the plastic surface a rarefaction front starts back into the plastic at the same velocity at which the shock front moved outward.



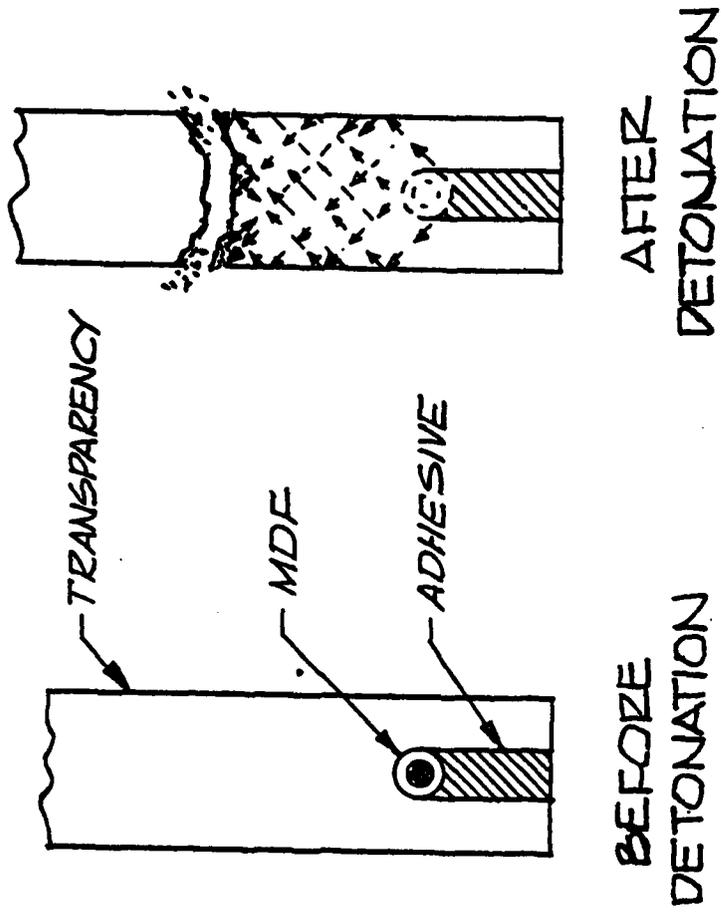


FIGURE 3
EDGE IMBEDDED MDF

3.4.1 Severance With Mild Detonating Fuse (MDF)
(Continued)

When two rarefaction fronts meet along a line, a fracture plane (surface) is produced. The fracture will propagate as the rarefactions move back into the material along the fracture plane.

The MDAC edge imbedded MDF concept is a variation of the sweeping detonation technique, wherein the bisector and bisectrix location is moved substantially away from the shock input stimulus of the MDF. This causes the shock wave to move angularly outward to the canopy material surfaces then reflect at a right angle back into the material to a point where rarefaction occurs and fracture plane develops. The result is a very clean, fragment free severance.

This concept can be incorporated into the T-38 canopy, however, the forward and aft edge attach becomes complicated when compared to the present forward and aft configuration. Figure 4 illustrates two configurations for forward and aft arch edge attachment. In each case the structural integrity for bird resistance is compromised. The slotted configuration on Figure 4 is so poor in tension that the slots will have little effect in retaining the canopy on the arch during bird impact. The second configuration of Figure 4 will potentially fail in compression during bird strike, thus allowing some portion of

3.4.1 Severance With Mild Detonating Fuse (MDF)
(Continued)

the bird to enter the cockpit area. The alternative approach is to utilize edge imbedding on the rear and sides of the canopy without edge imbedding on the forward edge.

Edge imbedded MDF with alternate method of releasing the forward canopy edge is a candidate for the T-38 application.

SPACE ORDNANCE SYSTEMS

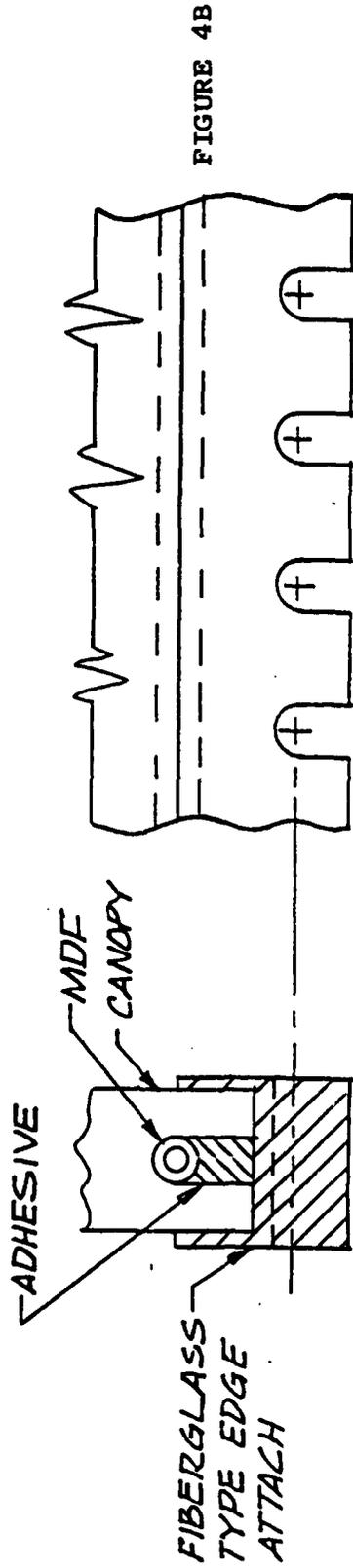
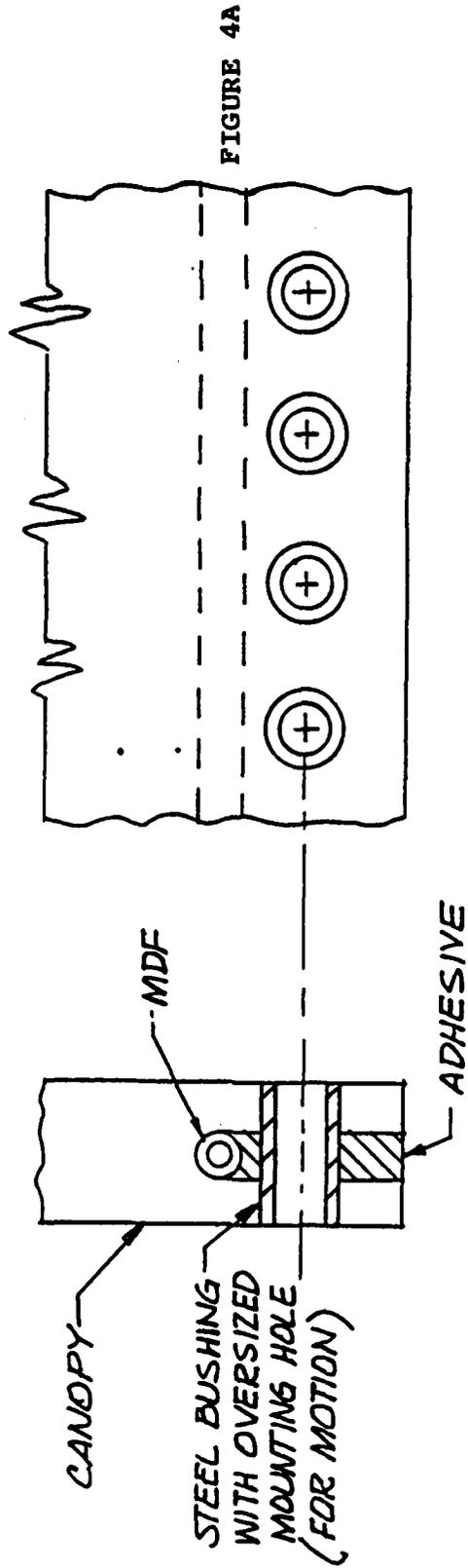


FIGURE 4
TYPICAL FORWARD & AFT EDGE ATTACH
FOR EDGE IMBEDDED MDF

SOS

3.4.2 Severance With Flexible Linear Shaped Charge (FLSC)

FLSC like MDF is a continuous explosive core enclosed in a seamless metal sheath. FLSC is shaped in the form of an inverted "V" and the continuous liner and explosive produce a linear cutting action which is vastly more efficient than MDF. FLSC is widely used for missile stage separation, vehicle destruct and crew escape systems and other applications where remote, fast, reliable cutting of materials is required. FLSC is used for crew egress on the B-1, F-111 and many experimental aircraft wherein a metallic panel is cut away to provide an escape path or route.

The explosive phenomenon known as the Munroe Effect is generally described as the interaction of the detonation products and cavity liner material emanating at high velocity from a shaped charge as the explosive detonates. The explosive decomposition releases large quantities of gas almost instantaneously under extreme pressure - as much as several million pounds per square inch. In FLSC, shock waves produced by the expanding gases move outward radially as well as longitudinally, and conform generally in shape to the cross section.

The shock waves emanating from the lower portion of a typical



3.4.2 Severance With Flexible Linear Shaped Charge
(FLSC) (Continued)

FLSC converge in a plane parallel to the cord axis and cause an extreme pressure concentration along the plane of convergence. These directed shock waves, together with the products of explosive decomposition and the metal fragments from the sheathing material, form the primary cutting action - the jet. Deformation of the target material begins within one microsecond of the passage of the detonation front at any given point on the FLSC.

Figure 5 illustrates the formation of the cutting jet beginning with Figure 5A which shows the FLSC cross section prior to detonation. At T_d (time of detonation) plus .25 microseconds (Figure B), the detonation products have begun to move outward, expanding and cracking the metal sheath, but not rupturing it. A thickening at the liner apex indicates the jet is beginning to form. By T_d plus .50 microseconds (Figure 5-C), the detonation products have begun to vent through the disintegrating metal sheath. The shock waves produced by the expanding gases and the cavity liner material emanating from the lower portion of the FLSC are converging, the jet is taking definite form, and penetration of the target is beginning.



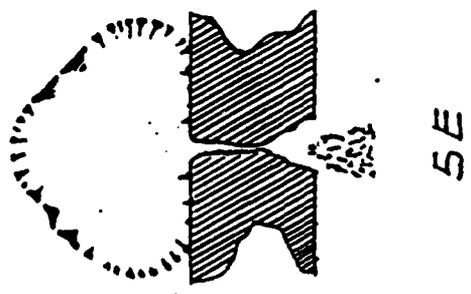
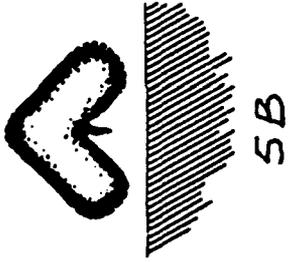
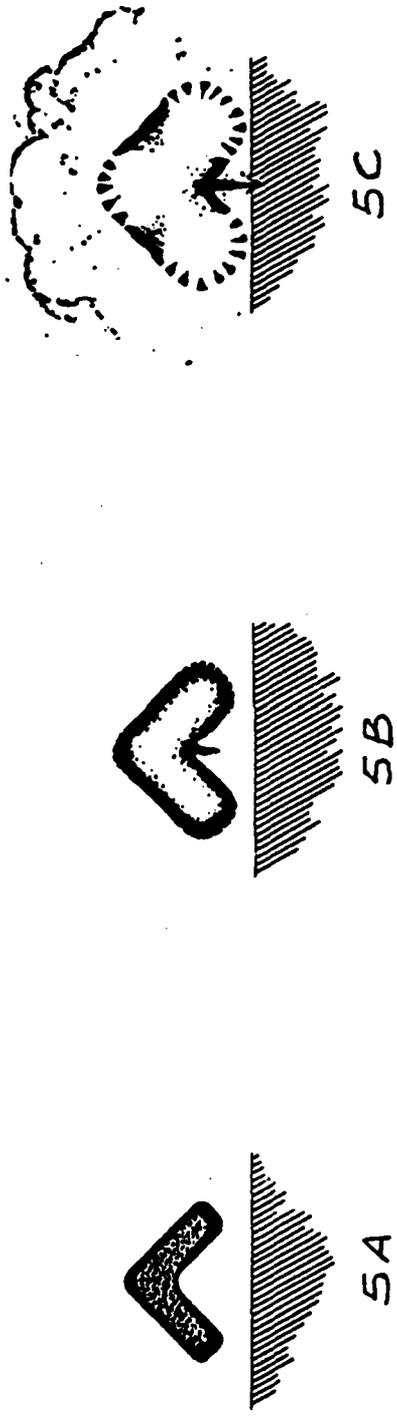


FIGURE 5
FLSC CUTTING PROCESS

3.4.2 Severance With Flexible Linear Shaped Charge (FLSC) (Continued)

In Figure 5-D (T_d plus 1.0 microseconds), the jet is fully developed and deformation of the target is well under way.

Typically, if a length of FLSC is detonated on a metal witness plate, the jet exerts a force of several million pounds per square inch along a very narrow line. This force causes the metal to be pushed out of the way of the advancing jet by plastic flow. The resulting groove is commonly termed "penetration". On a relatively thin plastic plate as used for canopy transparencies the performance of FLSC depends not only on the cavity liner material and the intense, directed shock waves to erode the target, but also on the rapidly expanding gases to physically dislocate and fracture it. The shock waves, when reflected from the surface opposite the cut, can also cause spalling from that surface. The total effect is termed "cutting." FLSC consistently cuts a target of greater thickness than can be penetrated. Normally with plastic materials the penetration groove will be 60 percent of the total plate thickness. The remaining 40 percent of the plate will be severed by spalling (shock fragmentation).

3.4.2 Severance With Flexible Linear Shaped Charge
(FLSC) (Continued)

The total cutting action results in a clean severance with some fragmentation of the outer edge on both sides of the severance plan.

The cutting ability of FLSC is an inverse function of the square root of the density of target material. This is described by the equation

$$t = t' \sqrt{\frac{\rho'}{\rho}}$$

where t is the unknown thickness of a material with known density, ρ , and t' is the known thickness of a material of density, ρ' , which has been cut by the FLSC. For example, FLSC of a given size will cut a greater thickness of aluminum than steel. Equivalent thicknesses of more dense materials require larger explosive coreloads.

FLSC is available that will cut several inches of steel as well as significantly greater thicknesses of aluminum and other less dense metals. FLSC will also easily sever most synthetic structural materials such as ablatives and reinforced plastics.

3.4.2 Severance With Flexible Linear Shaped Charge
(FLSC) (Continued)

FLSC is a candidate for use on the T-38 Canopy. Several severance patterns can be implemented with FLSC since the cord and holder can be surface mounted on the interior of the canopy. Mounting can be accomplished by adhesive bonding directly to the canopy, or a backing plate can be used to hold the FLSC and holder against the canopy.

By virtue of its density and elastic properties, polycarbonate is an ideal candidate for FLSC cutting. The cutting and spalling action of FLSC is predictable and reliable for any given thickness of polycarbonate. Design features such as interlayers and laminations will vary the required core loading of the FLSC when compared to monolithic designs. A two ply cross section with interlayer can reliably be cut, but 30% - 50% higher explosive core loading is required for this configuration as compared to the monolithic. The interlayer acts to disperse and attenuate the FLSC directed shock waves. The result is a reduction of the spalling action penetration depth. As stated on Page 20, the FLSC jet plasma penetration represents 60% of the total cut, while the remaining 40% of the cut is attained by spalling or shock wave reflection fracture. The additional 30% - 50% extra core load is required to overcome the losses at the interlayer. SOS has successfully

3.4.2 Severance With Flexible Linear Shaped Charge
(FLSC) (Continued)

severred 0.75 thick laminated polycarbonate (2 ply -.375 thick plates bonded together) using 20 grain per foot FLSC. This 2 piece configuration required a higher explosive core load than a monolithic due to the break up of penetration and spalling action created by the interface of the two plates. This testing verifies that laminated and the interlayered configurations in the T-38 bird resistant thicknesses can be readily cut with FLSC. This testing further demonstrates that a reasonable FLSC core loading will reliably sever the anticipated 0.40 thick monolithic polycarbonate proposed in PPG Technical Proposal Number NP1585R01.

3.5 Canopy Removal After Severance

One of the canopy severance candidates for the T-38 canopy is a full perimeter severance pattern. This pattern cuts the entire transparency to provide an escape path. The question here is not cutting the transparency, but how can the canopy be removed from the ejection path?

3.5 Canopy Removal After Severance (Continued)

Five basic techniques have been used to clear the canopy for ejection. Each technique is briefly described below.

Canopy Centerline Severance

The canopy is explosively cut along its centerline and ejection through the canopy provides the required breakout. This technique is incorporated on the A-7K Aircraft which utilizes an acrylic transparency. This concept is not feasible for the T-38 because the centerline cut will not sufficiently degrade the polycarbonate transparency to allow ejection without injury to the student pilot.

Seat Mounted Canopy Piercing

A seat mounted cutting blade is provided and during ejection the blade breaks the canopy as the seat and crew member pass through. This technique is presently used as a backup for the canopy jettison system on the T-38 aircraft. The bird resistant canopy was analyzed to determine if the piercing concept is feasible for the T-38. This published work is entitled "Finite Element Analysis of Through the Canopy Emergency Crew Escape from the T-38 Aircraft" was conducted by R.E. McCarty and R.A. Smith of the WPAFB Flight Dynamics Laboratory, Crew Escape and Subsystems Branch. Review comments pertinent to the "magna" analysis are as follows.

The MAGNA analysis indicates that a seat mounted canopy breaker might be capable of breaking through a .40 thick polycarbonate canopy utilizing the force available with the existing seat catapult. The analysis further states that the biodynamic response of the student pilot body to the resulting acceleration may be unacceptable when considering the acceleration and deceleration loads anticipated. The analysis is a nice piece of work, but the conclusion section ignores canopy breakout of the required ejection envelope. Ejection requires a clear path for the seat and student pilot head and extremities. The forces required to open up the seat - man envelope combined with the sharp, ragged fracturing canopy would surely cause severe injury as the student pilot passed through. We consider through the canopy ejection to be a totally unacceptable concept for the T-38 bird impact resistant canopy.

3.5 Canopy Removal After Severance (Continued)

Total Canopy Fracture

The canopy is explosively fractured into small fragments and the seat/crew member eject through the canopy plane. This technique is utilized in conjunction with acrylic canopy transparencies wherein the primary and interacting shock waves can reliably break up the canopy. The British Harrier and XTV Aircraft incorporate this technique for clearing the canopy for ejection. This technique is not possible with polycarbonate transparencies. The polycarbonate material is resistant to the cracking and crack propagation characteristics required for success of the total Canopy Fracture technique.

Canopy Jettison

A ballistic thruster is used to drive the canopy pivoting mechanism up into the airstream and clear of the ejection path. This technique is widely used and is presently incorporated in the T-38 Aircraft. The existing jettison system will continue to be the primary mode of canopy removal for the T-38 Aircraft. The new canopy system weight is dependent primarily on the transparency design ultimately chosen for bird proofing. This additional weight varies from 15 to 45 pounds with the different transparency designs. This additional weight will have a degrading effect on the existing thrusters. Should the capabilities of the thrusters be exceeded, they could be replaced with more powerful thrusters.

Canopy Mounted Rocket Motor Jettison

Solid propellant rocket motors are mounted to the canopy frame or side rails. When the canopy is released the rocket motors thrust the canopy up and clear of the ejection path. This technique is used on the F-16 and F-18 Aircraft and performance is within system requirements for each application. This concept could be utilized on the T-38 in conjunction with full perimeter severance for canopy removal. Use of the F-16 or F-18 rocket motors would improve canopy jettison performance because the T-38 canopy is much smaller and lighter. Two motors would be used for the T-38 with one bolted directly to the canopy transparency in each forward lower corner.

3.5 Canopy Removal After Severance (Continued)

Canopy Mounted Rocket Motor Jettison (Continued)

The potential for student pilot burn hazard exists with rocket motor exhaust blast unless attention is given to the problem. This hazard can be eliminated in the manner discussed below.

A blast deflector for the rocket motors can be designed which will direct the hot gas output away from the student pilot during ejection. Test results for the F-18 aircraft (reference MDAC Report Number MDCA7127) verifies that the elapsed time between rocket motor ignition and canopy separation from aircraft is only 0.083 seconds. Canopy separation from the F-18 occurs after the canopy has rotated up and back in a 45° arc.

The short time duration of rocket motor blast (0.083 second) combined with blast deflectors for the T-38 will negate the possibility of injury due rocket gas output. This rationale justifies the rocket motors for consideration as a possible candidate for T-38 canopy removal.



4.0 DESIGN CONCEPT REVIEW - INITIATION SYSTEMS

This section contains design concepts developed for the T-38 program which are considered to be the most feasible for implementation. Initiation systems are reviewed independently of the canopy severance concepts in as much as initiation is considered to be a distinct and separate function. The initiation concepts described herein may be integrated with any of the canopy severance concepts described in paragraph 5.0.

The criteria used during concept selection was as follows;

- MINIMIZE T-38 MODIFICATION
- CONSIDERATION OF INJURY TO AIR AND GROUND CREWS
- NO DEGRADATION OF PRIMARY EJECTION SYSTEM
- COMPATIBILITY WITH T-38 AIRFRAME AND SYSTEMS
- RELIABILITY
- NO SCHEDULED MAINTENANCE
- FUNCTION AFTER BIRD STRIKE
- REDUCTION OF PRE-EJECTION TIME DELAY
- MINIMIZE GROUND EGRESS TIME DELAY
- ALL PYROTECHNIC OUTPUT MUST BE CONTAINED TO ELIMINATE INJURY, FIRE OR EXPLOSIVE HAZARD IN THE EVENT OF FUEL SPILL

Two basic methods for initiation have been selected

- Gas Initiation Delivered To Rocket Catapult - See Figure 6 for gas takeoff from primary system.
- Seat Handle Initiation - See Figure 7 for location of lanyard control cable installation.

The existing T-38 Crew Escape System schematic is shown on Figure 8 for Reference purposes.

SPACE ORDNANCE SYSTEMS

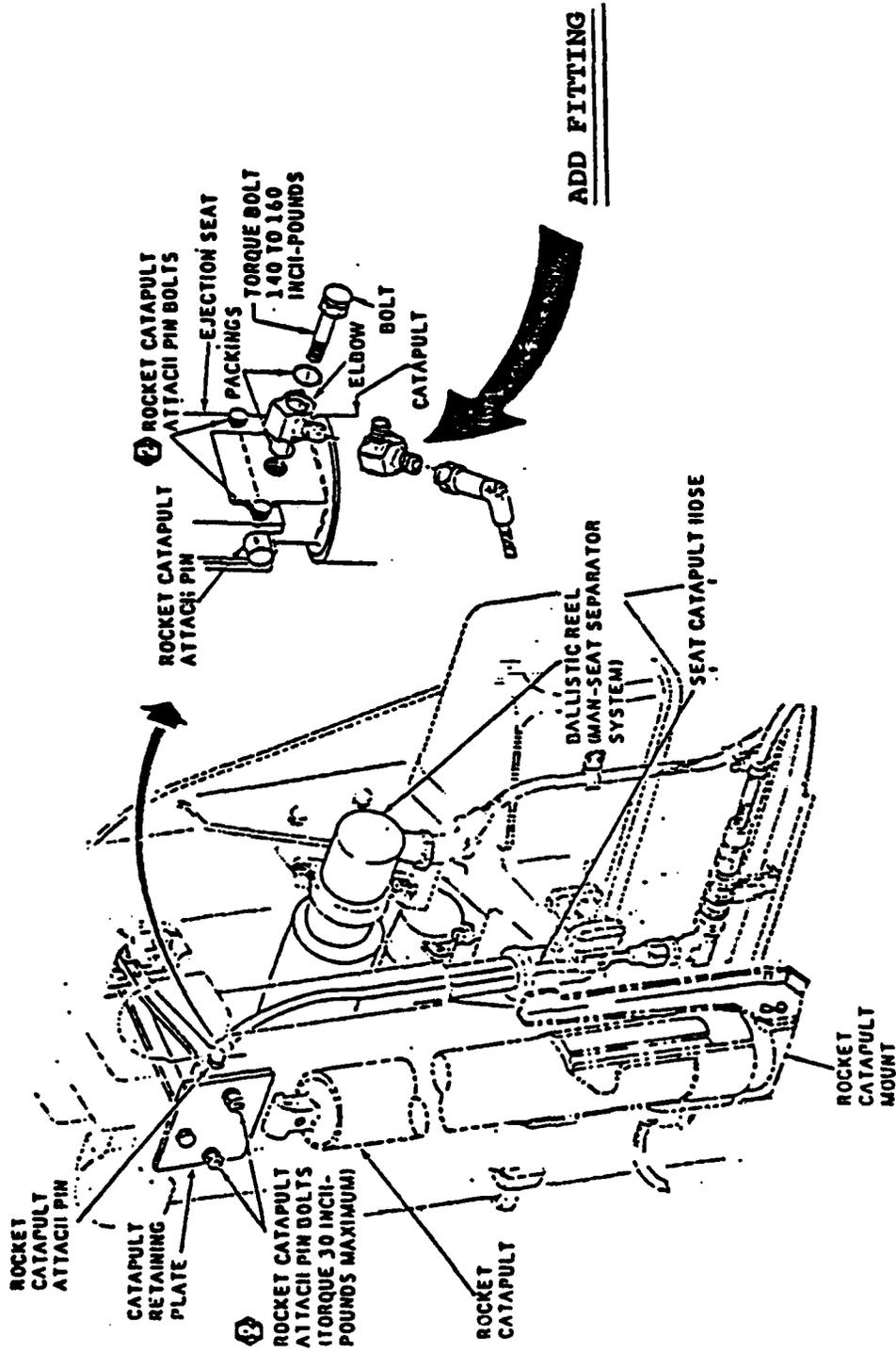


FIGURE 6
TAKEOFF LOCATION FOR BALLISTIC GAS

SOS

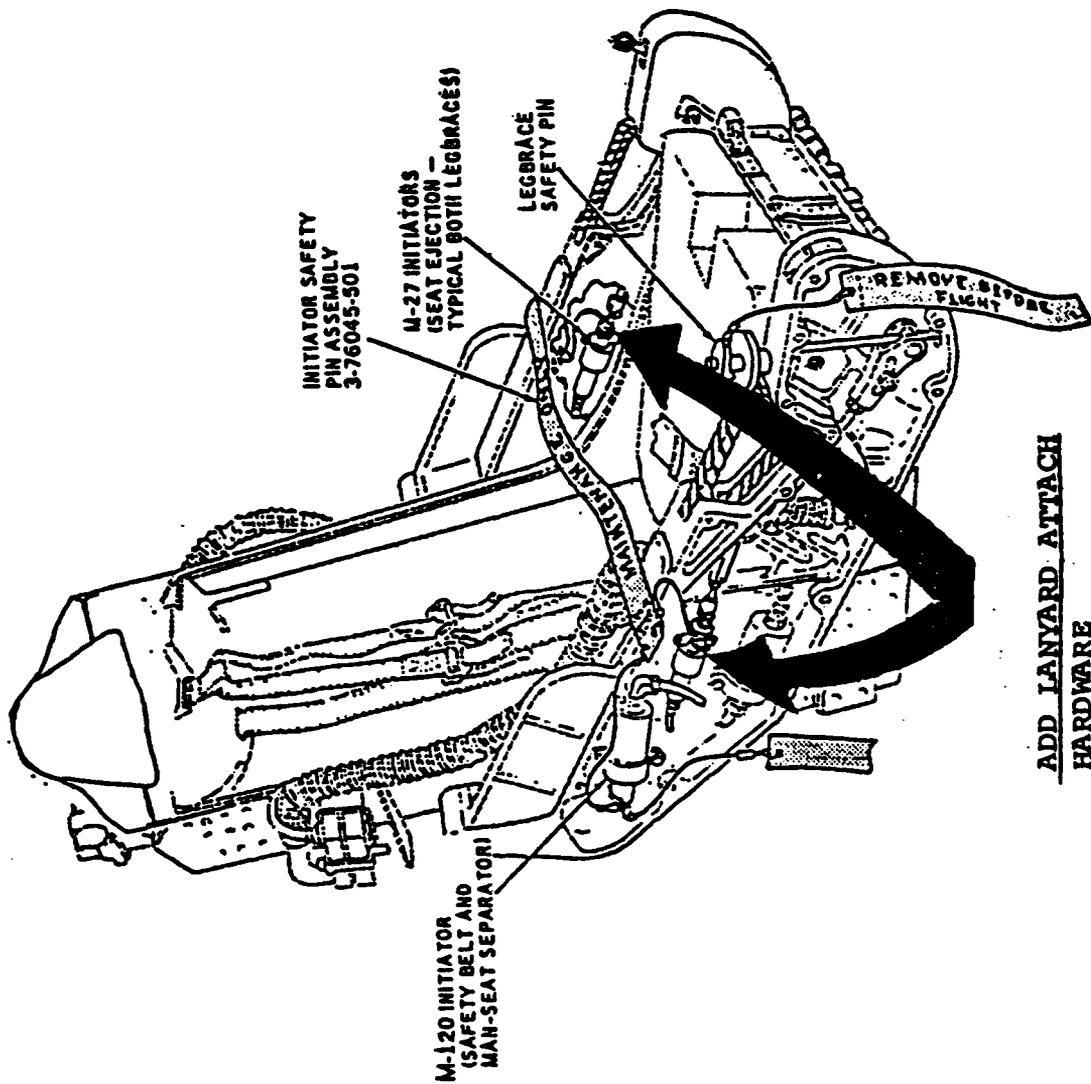
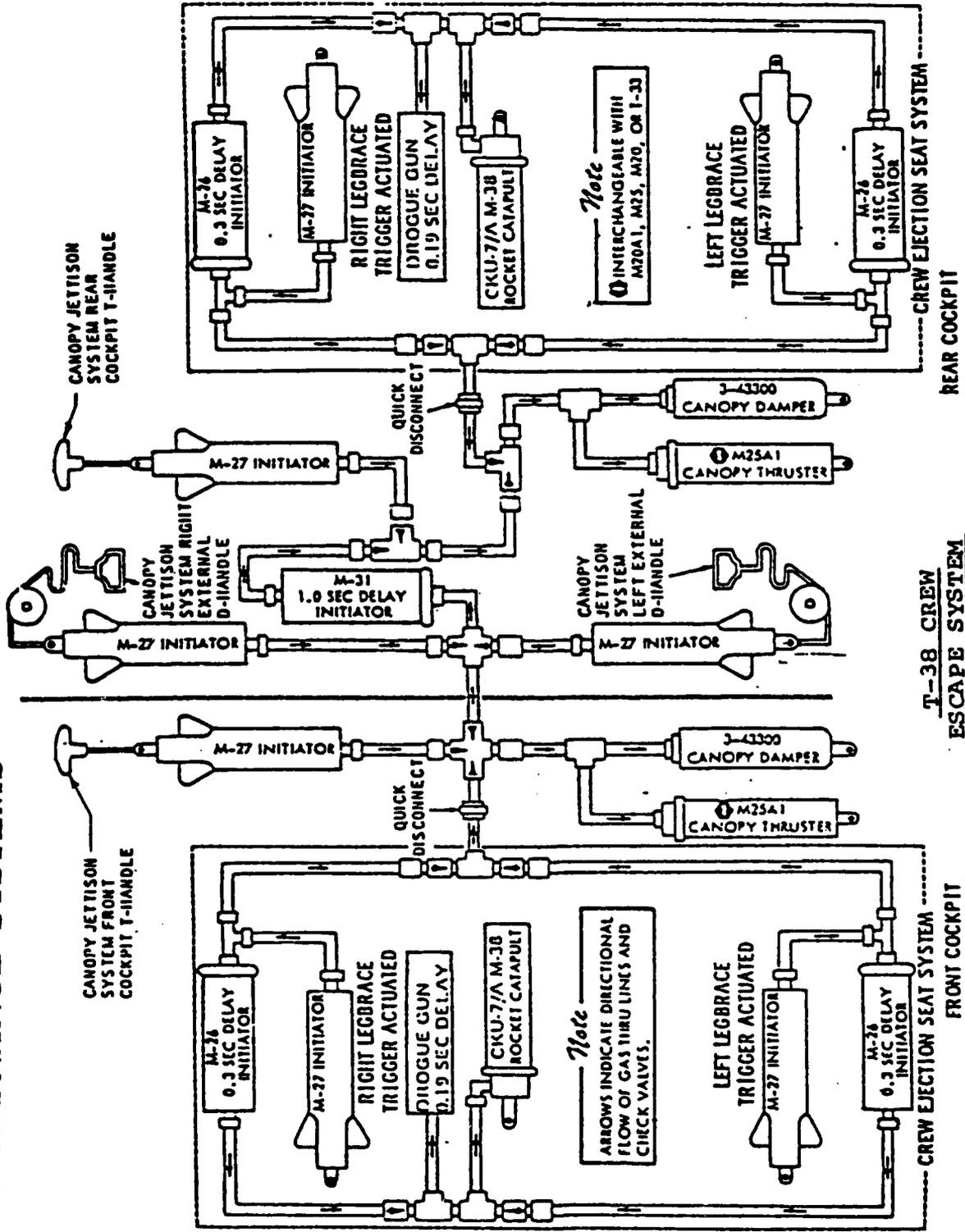


FIGURE 7
LANYARD CONTROL CABLE LOCATION

SPACE ORDNANCE SYSTEMS



T-38 CREW
ESCAPE SYSTEM
SCHEMATIC

FIGURE 8



4.0 DESIGN CONCEPT REVIEW - INITIATION SYSTEMS
(Continued)

The program philosophy SOS has chosen for the T-38 program is to "minimize the crew thought process for ejection or ground egress". This has led to system concepts which utilize student pilot input to the existing T-38 system in order to initiate the primary and clear path egress systems.

The existing T-38 Crew Escape System (Primary System) inputs are utilized for initiation of the back up Clear Path Egress System. The egress modes and their respective crew actuation points are described below:

In Flight Ejection - Initiated by pulling the two seat mounted leg brace initiator handles. This initiates the Primary and backup Clear Path Egress System.

Ground Egress, Aircrew Initiated - Initiated by pulling the T-Handle lanyard mounted under the instrument panel on the right handside. This initiates the primary canopy jettison system and the backup Clear Path Severance System.

Ground Egress, Ground Crew Initiated - Initiated by pulling the external D-Handle lanyards on each side of the aircraft. This initiates the Primary Canopy Jettison System and the backup Clear Path Canopy Severance System.



4.0 DESIGN CONCEPT REVIEW - INITIATION SYSTEMS (Continued)

By using the Primary System input points to also initiate the backup Clear Path System the time consuming decision making process is totally eliminated.

This philosophy was followed in all of the concepts for in-flight ejection, and for ground egress in all but one of the final concepts. Concept Number 1 utilizes independent initiators for ground egress. In some ground egress cases it may be desirable to select either the primary canopy jettison mode or the CPE canopy jettison mode. For this purpose a separate input for CPE ground egress can be added for aircrew and ground crew actuation. This would make the CPE ground egress system totally independent of the primary system.

It should be noted that the initiation concepts presented, although they possess explosive or pyrotechnic materials, will not cause fire or explosion in a fuel spill environment. All products of combustion capable of fuel or fuel vapor ignition are confined within the system components. In this regard the proposed initiation concepts like the present system, present no risk.



4.0 DESIGN CONCEPT REVIEW - INTIATION SYSTEMS
(Continued)

Space availability within the T-38 cockpit area and ground crew canopy jettison hatches is minimal. However, careful inspection of the aircraft verifies that sufficient room is available for components of the proposed concepts described herein.

4.1 Primary Gas Initiation System

In-flight ejection for the T-38 Aircraft Primary System is initiated by actuating the seat handles mounted on the right and left leg braces of the seat. Seat handle actuation fires an M-27 Initiator which in turn fires a 0.3 Second Time Delay Initiator. The 0.3 second Time Delay is provided to allow function time for canopy jettison and the shoulder harness inertia reel. Ballistic gas from the 0.3 Second Time Delay Initiator fires the seat mounted rocket catapult and the pilot and seat are ejected from the aircraft.

The gas initiation system for the in-flight backup or Clear Path Egress System receives its input stimulus from the 0.3 Second Time Delay Initiator within the T-38 Primary System. Figure 6 illustrates the takeoff location for gas at the rocket catapult input port. A high pressure pneumatic "Y" fitting and flexible line are provided to supply ballistic gas to the Gas/SMDC Initiator.



4.1 Primary Gas Initiation System (Continued)

A study was conducted to verify that the primary system would not be degraded by adding the free volume necessary to actuate the CPE initiation system. The study verifies that the primary system will not be degraded and in fact there is a substantial safety margin even with the added free volume.

Performance data for the M-26 Initiator was obtained from equipment specialist, Mr. Harold Hicks at Hill Air Force Base. The data was taken from a scheduled program for M-26 Initiators where units are pulled from inventory and tested to verify compatibility with the CKU-7 Catapult.

At -65°F the minimum M-26 output is 1657.6 PSI with first indication of pressure within 26.1 milliseconds after actuation. The test setup consists of 36 inches of 1/8 inch flex hose feeding into a 10.0 cc closed bomb (total free volume equals 17.23 cc). Comparison of free volume of 17.23 cc with 1657.6 PSI min equals 96.1 PSI/cc. The last surveillance test results at Hill AFB provided 1,899 PSI average with first indication of pressure occurring at 22.8 milliseconds after actuation. Comparison of free volume of 17.23 cc with the 1,899 PSI equals 110 PSI/cc. The added free volume for the T-38 CPE system will be 0.88 cc (18 inches of 1/16" diameter line) when added to the 17.23 cc test volume provides a total of



4.1 Primary Gas Initiation System (Continued)

18.11 cc. The added length of line free volume reduces the pressure per cc to 104.85 PSI per cc which compares favorably with the 96.1 PSI per cc minimum requirement.

Further investigation verifies that the CKU-7 Catapult fires successfully with pressures of 250 to 400 PSI. Inventory acceptance testing of the CKU-7 Catapult is conducted at Hill Air Force Base at -65°F and at $+165^{\circ}\text{F}$. When the CKU-7 Catapult is tested at -65°F the input pressure is between 300 and 375 PSI. When tested at $+165^{\circ}\text{F}$ the input pressure is between 250 and 300 PSI. These input pressures are used to verify input pressure levels required to initiate the CKU-7. The input pressure is increased from zero at a low rate until initiation occurs. This information was obtained from Mr. Don Burton, CKU-7 Equipment Engineer at Hill Air Force Base. This CKU-7 data verifies that a significant safety margin is available for the primary system. The additional 0.8 cc of free volume added by the high pressure line to the gas/SMDC Initiator will have no degrading effect on the primary system.

Concepts 1, 2, 3 and 4 each use the gas initiation method for in-flight ejection. The variations for each concept are in the Gas/SMDC Initiator and its mounting location, and the ground egress feature configuration.



4.1.1 Concept Number 1 - Gas Initiation/Independent
Ground Egress Initiators

4.1.1.1 In-flight Egress

This design is shown schematically on Figure 9. The Gas/SMDC Initiator for this system is shown on Figure 10. The Initiator will be mounted on the bulkhead behind the student pilot's seat. SMDC Energy Transfer lines are utilized to transfer detonation from the Initiator out to the two Transfer Manifolds. The Transfer Manifold is shown on Figure 11. The Transfer Manifold consists of two halves, one half contains the donor SMDC Tip and the other half contains the acceptor booster for the Canopy Severance Charge. The donor half of the manifold is hard mounted to the cockpit structure and the acceptor half is mounted to the canopy frame. With the canopy down and locked the donor and acceptor charges are aligned for detonation transfer. When the canopy is up, the acceptor and donor are mis-aligned and detonation can not be transferred. Reliable detonation transfer can be attained with axial misalignment up to 0.25 inch and radial misalignment up to $\pm .070$. The transfer manifold is designed to be adjustable after canopy installation. This feature eliminates misalignment except as anticipated during normal open-close cycling of canopy.



4.1.1.1 In-flight Egress (Continued)

A safety Barrier is incorporated in the transfer manifold. A spring loaded Barrier slides over the output end of the Donor SMDC Tip when the canopy is open. This feature prevents personnel injury in the event of inadvertent SMDC firing. The Barrier also serves to protect the output tip from damage and contamination entrapment. Pulling the Barrier out of line can be accomplished using the canopy actuating linkage coupled to the Barrier Actuator Rod. The Transfer Manifold installation is shown on Figure 12.

4.1.1.2 Ground Egress

The ground egress system consists of three "L" Handle Initiators. One Initiator is mounted in the cockpit for student pilot actuation. The other two Initiators are mounted on each side of the aircraft for ground crew actuation in the Canopy Jettison handle storage compartments. The Ground Egress Initiator is shown on Figure 13.

SMDC Energy Transfer Lines connect the Initiators to a Junction Manifold which in turn provides an input into the Gas/SMDC Initiator.

When acutating the ground crew canopy jettison initiators there are two potential injury hazards; one is being hit by the



4.1.1.2 Ground Egress (Continued)

jettison canopy and the second is being hit by small segments of canopy spalled from the severance plane of the transparency. Both of these potential hazards can be eliminated by personnel positioning prior to canopy jettison and observing trajectory of the canopy. When actuating the L handle initiators the personnel should position themselves so that they are not directly in line with the canopy severance plane. In all normal aircraft attitudes this is mandatory since the ground canopy jettison hatch is below and to the rear of the canopy. However, with the aircraft in an inverted attitude, a position to the rear of the canopy should be assumed prior to canopy jettison. The small segments spalled from the transparency have little kinetic energy and will be directed straight out from the separation plane. If emergency apparel is worn then the spalled segments will not be capable of penetration when standing directly in line with the separation plane, albeit inadvisable.

Being struck by the canopy after jettison is really a matter of instruction and common sense. The potential of being hit by the canopy is present for the existing T-38 system as well as for the CPE system discussed herein. Pull the D handle or L handle and get out of the way. It would seem prudent to stay as close to the aircraft as possible using it as a shield

4.1.1.2 Ground Egress (Continued)

from the flying canopy, while observing the canopy's trajectory. The safest position would appear to be rear and below the canopy using the fuselage for protection.

4.1.1.3 Modification

Modifications to the T-38 Primary Ejection System are as follows:

- Disconnect input gas line from 0.3 Second Time Delay Initiator at the seat catapult rocket input port.
- Install "Y" fitting into catapult rocket input port.
- Re-install 0.3 Second Time Delay gas input line into one port of the "Y" fitting.
- Install flexible high pressure gas line for clear path system in second port of "Y" fitting.

Modifications to T-38 airframe are as follows:

- Install Gas/SMDC Initiator to bulkhead behind seat.
- Install "L" Handle Initiator in cockpit.
- Install "L" Handle Initiators in the ground crew canopy jettison storage compartments on each side of aircraft (2).
- Install SMDC lines from ground crew "L" Handle Initiators to the Gas/SMDC Initiator (2).
- Install the Transfer Manifolds to the cockpit structure adjacent to canopy (2).
- Install SMDC lines from Gas/SMDC Initiator to the Transfer Manifold (2).
- Install and adjust the canopy mounted half of the Transfer Manifolds (2).

Ejection seat removal is considered necessary.



SPACE ORDNANCE SYSTEMS

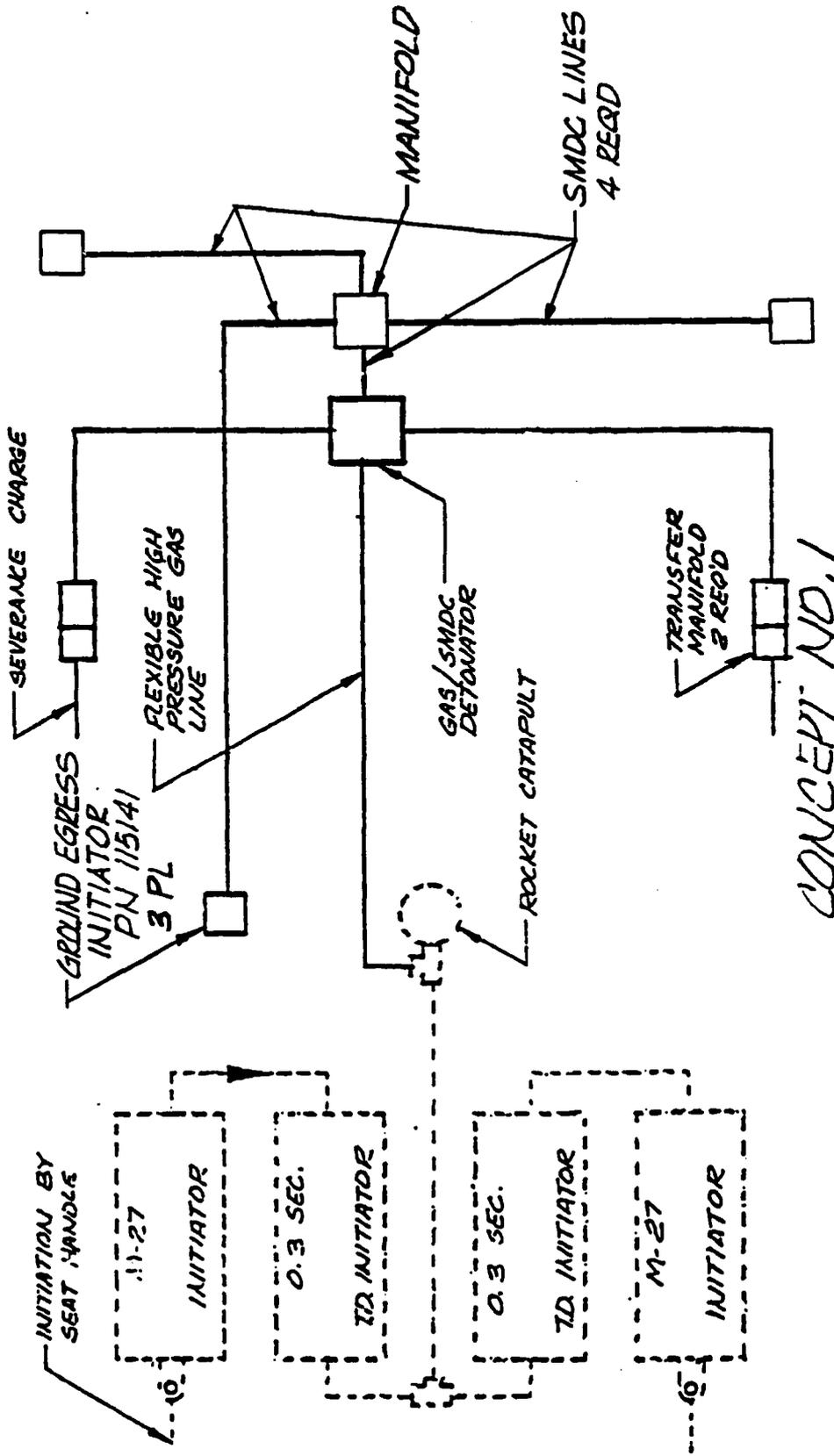


FIGURE 9
 GAS INITIATED SYSTEM
 WITH SEPERATE INITIATORS FOR
 GROUND EGRESS

SOS

SPACE ORDNANCE SYSTEMS

TO TRANSFER MANIFOLD

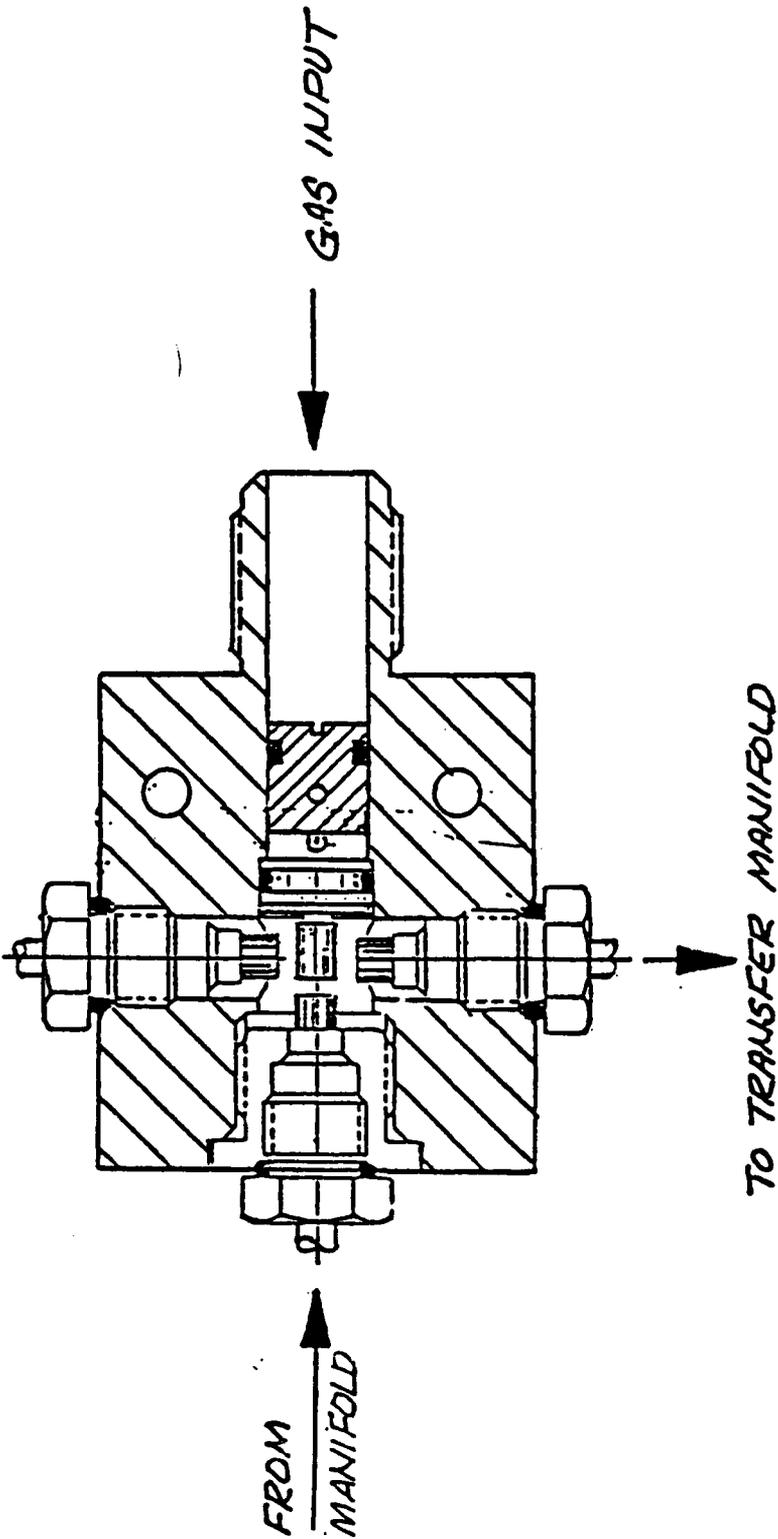
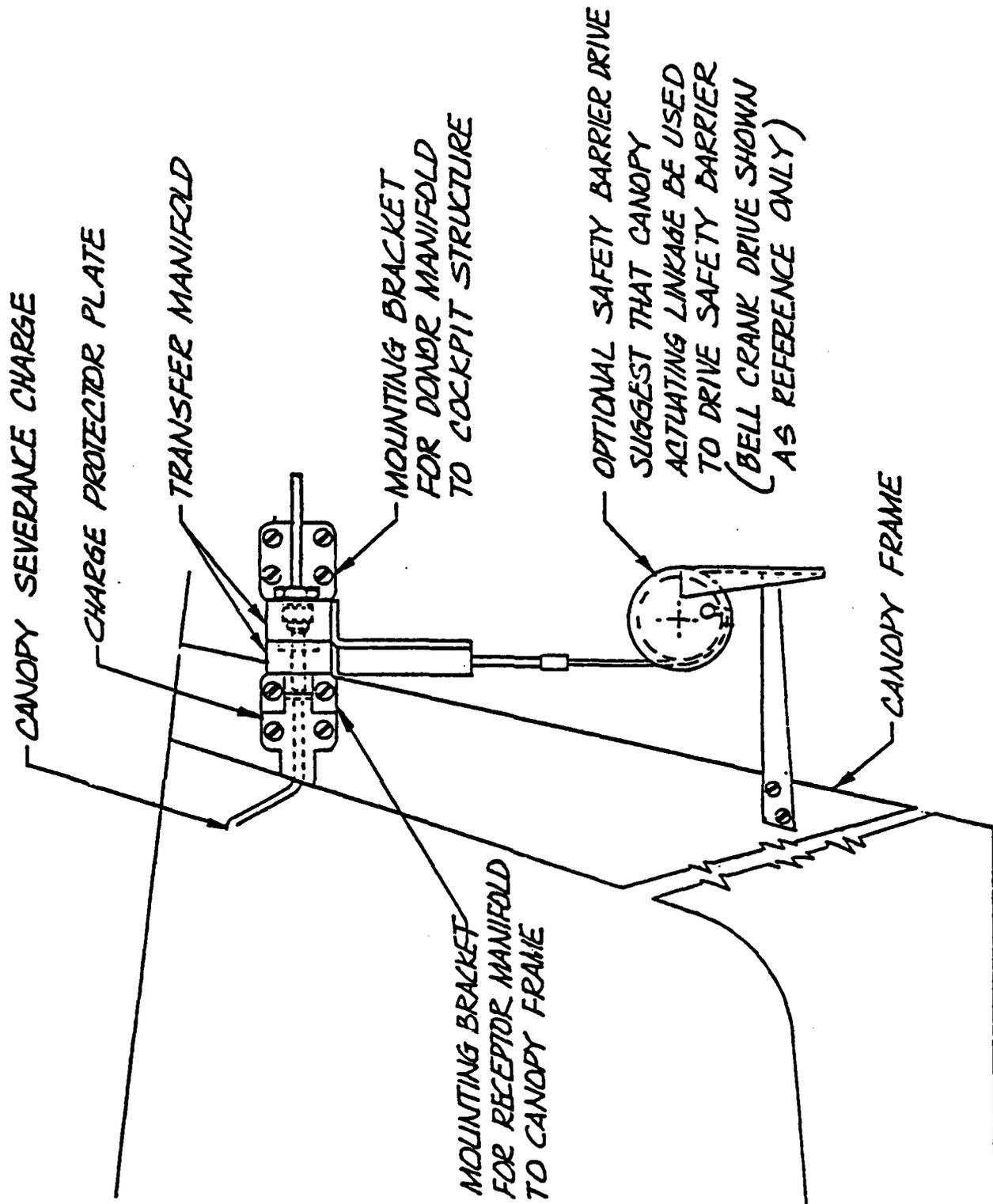


FIGURE 10
GAS/SMDC INITIATOR

SOS



TRANSFER MANIFOLD INSTALLATION

FIGURE 12

SPACE ORDNANCE SYSTEMS

4.1.2 Concept Number 2 - Gas Initiation/Cable Actuated Ground Egress

4.1.2.1 In-flight Egress

This design is shown on Figure 14. The Gas/SMDC Initiator used for this concept is shown on Figure 15. The Initiator will be mounted on the bulkhead behind the student pilot. SMDC Energy Transfer Lines and the Transfer Manifolds are identical to those described for Concept Number 1. Actuation of the Primary System leg brace handles also initiates the Clear Path Egress System.

4.1.2.2 Ground Egress

Initiation for ground egress is provided by a cable actuated detonator incorporated in the Gas/SMDC Initiator, refer to Figure 15. Actuation of the student pilot T Handle or either of the ground crew D Handles will initiate the ground egress system. This is accomplished using an attachment kit and control cable to connect each actuation handle to the Initiator. See Figure 20 for illustration of attachment hardware.

In this manner, actuation of the Primary System T and D Handles also initiates the Clear Path Egress System. Separate T&D Handles and Cables can be incorporated to provide independency from the primary system.

SPACE ORDNANCE SYSTEMS

4.1.2.3 Modifications

Modifications to the T-38 Primary Ejection System are as follows;

- Disconnect input gas line from 0.3 Second Time Delay Initiator at the seat catapult rocket input port.
- Install "Y" fitting into catapult rocket input port.
- Re-install 0.3 Second Time Delay gas line into one port of the "Y" fitting.
- Install flexible high pressure gas line for Clear Path System in second port of "Y" fitting.

Modifications to the T-38 airframe are as follows:

- Install Gas/SMDC Initiator to bulkhead behind student pilot seat.
- Install cable attachment kit to each of the three ground egress handles ("D" and "T") and to the Initiator.
- Adjust ground egress cables.



SPACE ORDNANCE SYSTEMS

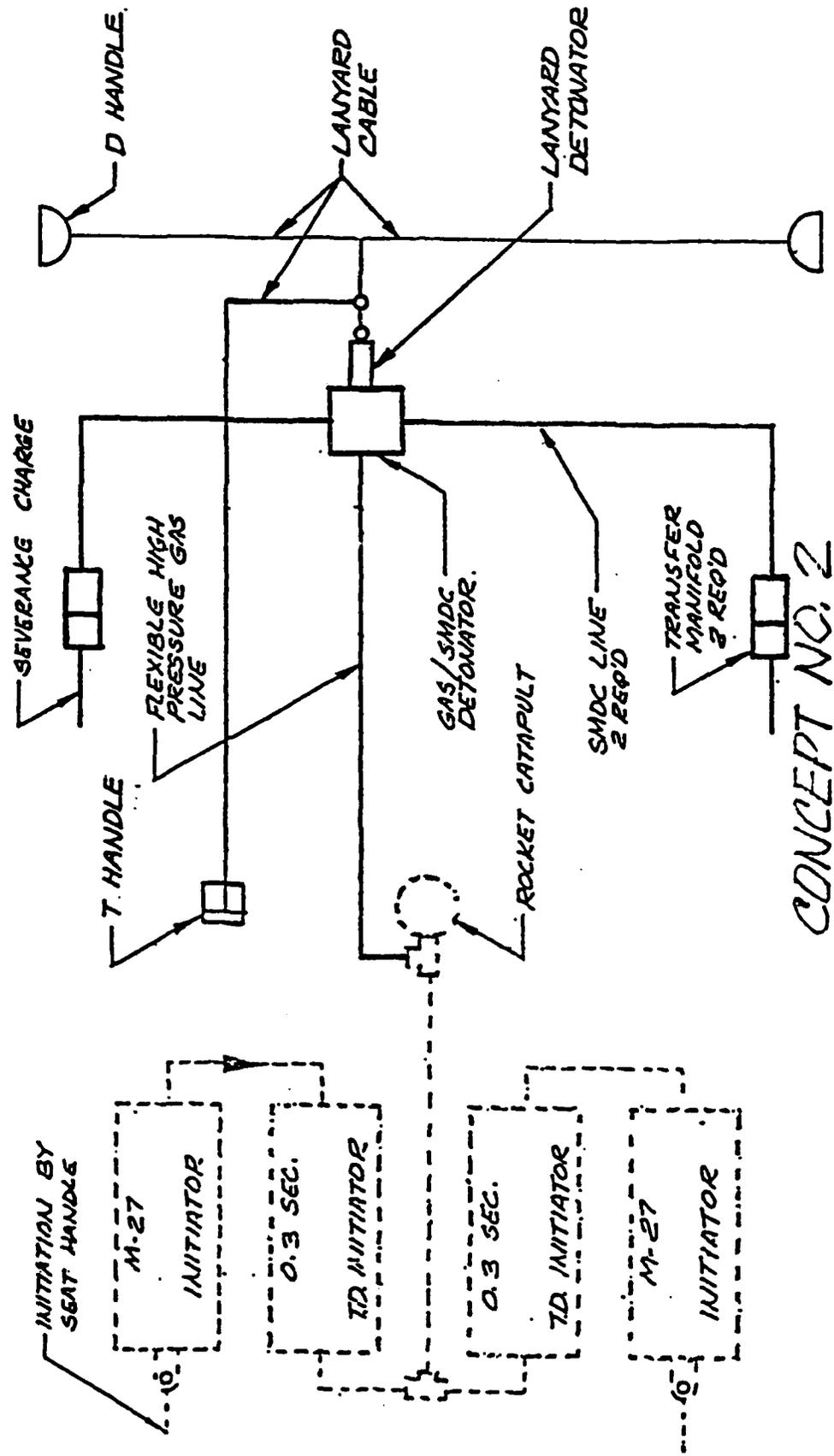
4.1.2.3 Modifications (Continued)

- ° Install cockpit mounted half of Transfer manifold to cockpit structure adjacent to canopy and adjust for alignment with canopy mounted half of Transfer Manifold.
- ° Install SMDC lines between Gas/SMDC Initiator and Transfer Manifolds (2).

Ejection seat removal is considered necessary for installation of this hardware.



SPACE ORDNANCE SYSTEMS



CONCEPT NO. 2

FIGURE 14

GAS INITIATED SYSTEM - BULKHEAD MOUNT INITIATOR
WITH LANYARD ACTUATED GROUND EGRESS

SOS

SPACE ORDNANCE SYSTEMS

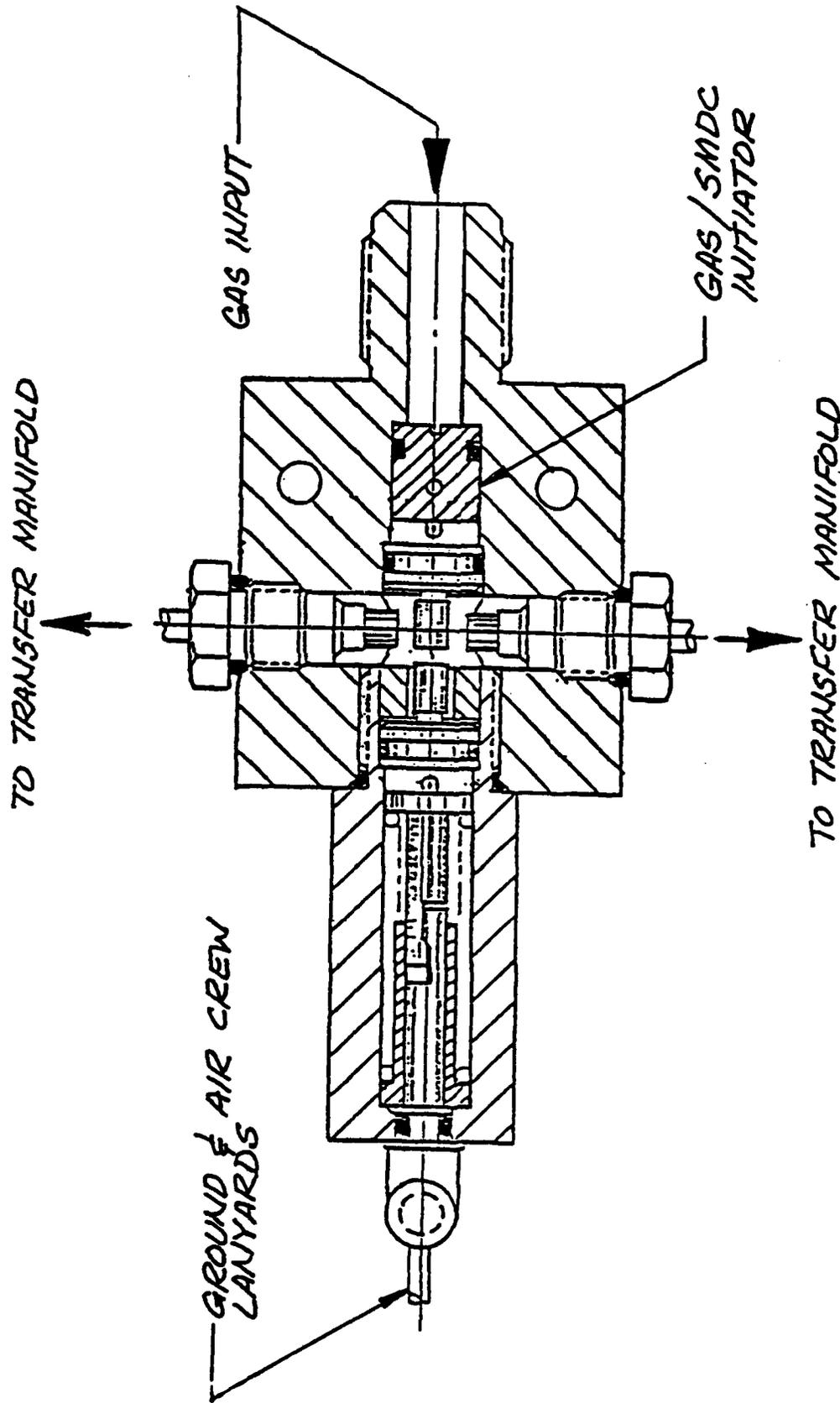


FIGURE 15

INITIATOR - GAS & LANYARD ACTUATED



4.1.3 Concept Number 3 - Redundant Gas Initiation and Cable Ground Egress, Canopy Mounted

4.1.3.1 In-flight Egress

This concept is shown on Figure 16. The Gas/SMDC Initiator is similar to that shown on Figure 15 except for the following variations:

- Dual gas inputs for redundancy.
- Dual lanyard cable inputs for redundancy
- Canopy severance charge threads directly into the SMDC ports

The Gas/SMDC Initiator is mounted directly to the canopy rear former. The flexible high pressure gas lines and flexible cables allow the canopy to open and close. The flexible gas line will not present a maintenance problem since the expected life exceeds 100,000 open-close cycles. This concept varies from concepts 1 and 2 in that no SMDC lines or Transfer Manifolds are necessary. This reduces initial component cost as well as aircraft modification cost. In addition, reliability is increased by virtue of parts count reduction and explosive air gap reduction.



SPACE ORDNANCE SYSTEMS

4.1.3.1 In-flight Egress

Mounting the initiator directly to the canopy rear former requires a length of approximately 30 inches for the high pressure flexible gas line. This effectively adds a free volume of 1.5 cc (0.09in³) to the primary ballistic gas system. As discussed in paragraph 4.1 this additional free volume will have no degrading effect on the performance of the primary system.

4.1.3.2 Ground Egress

Ground Egress for this concept is identical to Concept Number 2 as described in paragraph 4.1.2.2

It should be noted that actuation of the primary system inputs for in-flight ejection and ground egress also initiates the Clear Path Egress System. CPE ground egress can be made independent of the primary system by providing separate T&D handles for actuating the initiator.

4.1.3.3 Modifications

Modification to the T-38 primary ejection system are as follows:

- ° Disconnect input gas line from 0.3 Second Time Delay Initiator at the seat catapult rocket input port.
- ° Install "Y" fitting into catapult rocket input port.



4.1.3.3 Modifications (Continued)

- Re-install 0.3 Second Time Delay gas input line into one port of the "Y" fitting.
- Install flexible high pressure gas line for Clear Path System in second port of "Y" fitting.

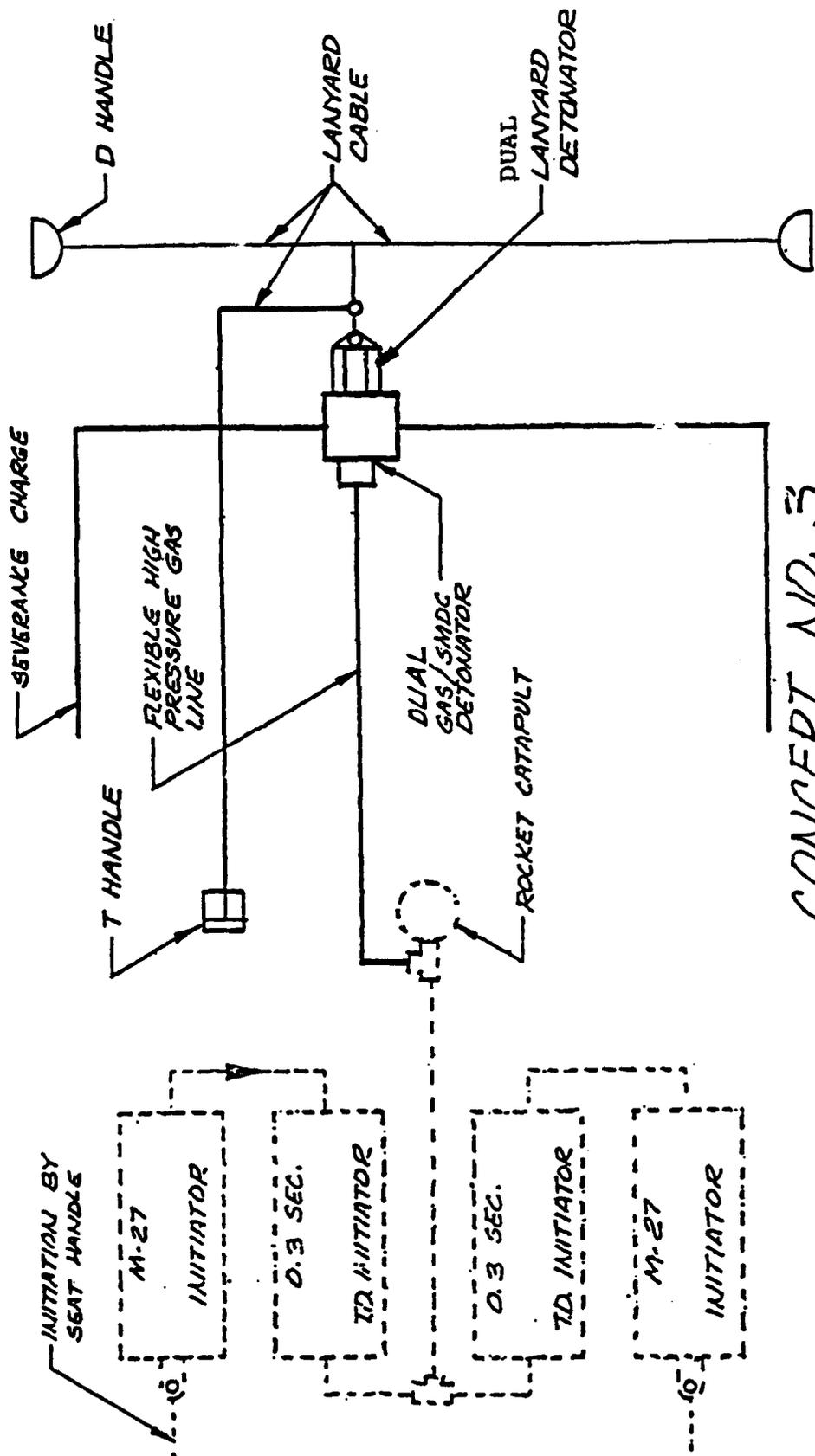
Modifications to the T-38 Airframe are as follows:

- Install cable attachment kit to each of the ground egress handles ("D"'s and "T") and to the Initiator.
- Adjust ground egress cables

Removal of the ejection seat or other airframe and systems components is not required.



SPACE ORDNANCE SYSTEMS



CONCEPT NO. 3

FIGURE 16

GAS INITIATED SYSTEM - CANOPY MOUNTED INITIATOR
WITH LANYARD ACTUATED GROUND EGRESS



4.1.4 Concept Number 4 - Dual Gas Initiation With Cable Ground Egress

4.1.4.1 In Flight Egress

This concept is shown on Figure 17. The gas actuated detonator is shown on Figure 18. Dual detonators are mounted on the canopy structure. The flexible high pressure gas lines and ground egress cables allow the canopy to open and close. No maintenance problem is anticipated with the flexible lines due to their 100,000 cycle life expectancy.

An SMDC crossover line is provided between the two detonators for the purpose of eliminating a single point failure potential. This feature is only required for severance concepts which do not contain a full loop severance charge.

Mounting the two detonators directly to the canopy requires a maximum length of 30 inches for the high pressure flexible gas line. An additional length of line (18 inches) is required to connect the two detonators together with a single input from the flexible line. A tee fitting and rigid line is envisioned for this purpose. The total pressure line free volume is estimated to be 2.37 cc. This added to the present T-38 test system free volume of 17.23 cc provides a total of 19.6 cc or an additional 13.8%. This compares favorably to

4.1.4.1 In Flight Egress (Continued)

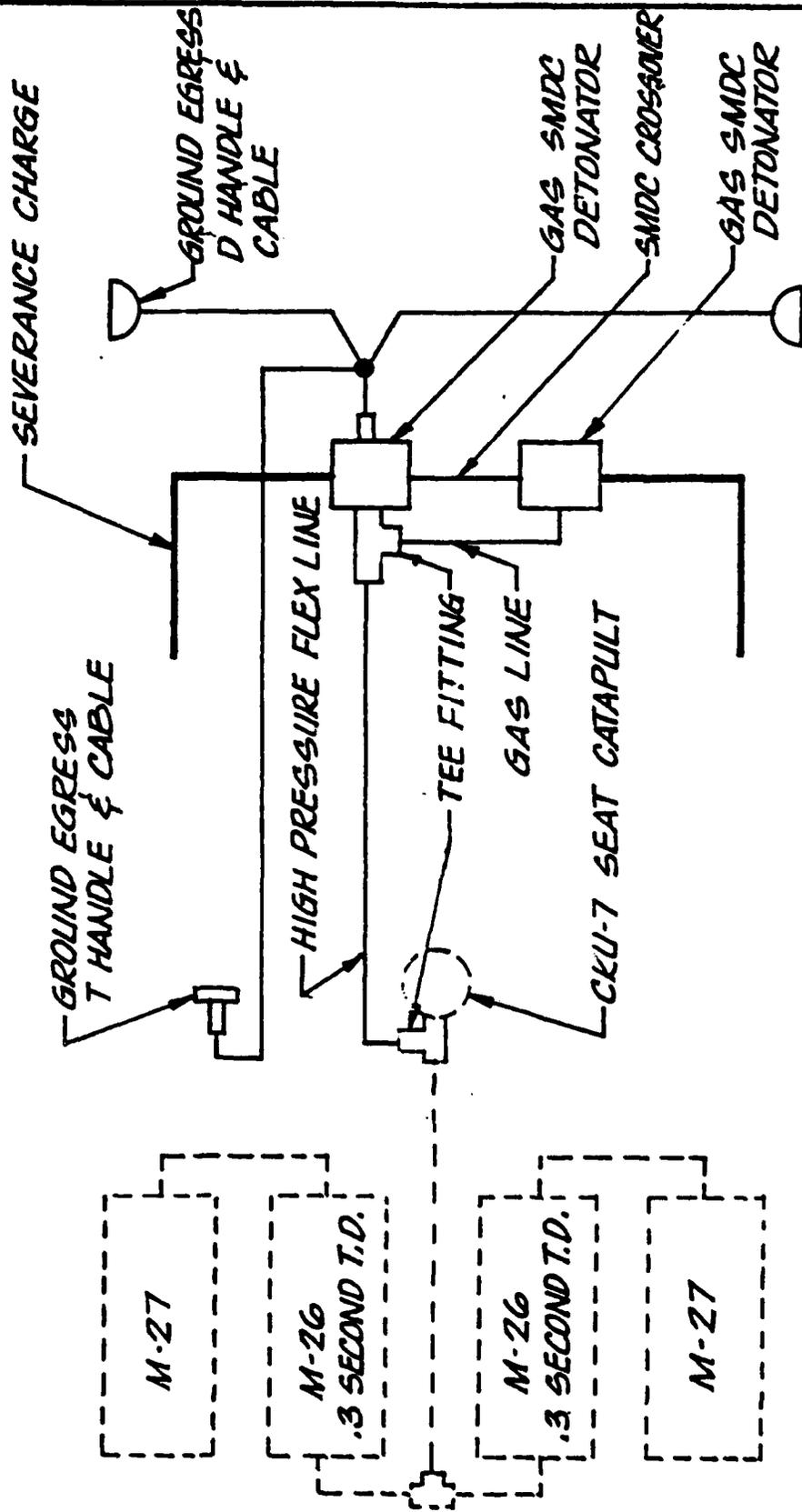
the actual T-38 system of 11.65 cc plus the 2.37 cc which equals 14.02 cc. The M-26 Initiator minimum output at -65°F is 1657.6 PSI into a free volume of 17.23 cc equals 96.2 PSI per cc. Assuming minimum pressure of 1657.6 PSI at -65°F with the proposed free volume of 14.02 cc for the aircraft system we have 118.23 PSI per cc. Based on this anticipated performance no system degradation is anticipated.

4.1.4.2 Ground Egress

Initiation for ground egress is provided by cable actuation of the detonator. Actuation of the student pilot T Handle or either of the ground crew D Handles will initiate the ground egress system. This is accomplished using an attachment kit and control cable to connect each actuation handle to the Initiator.

In this manner, actuation of the Primary System T and D Handles also initiates the Clear Path Egress System. Independent initiation of the CPE System is attainable by incorporating separate D&T Handles and Cables.

SPACE ORDNANCE SYSTEMS



CONCEPT NO. 4

FIGURE 17
DUAL GAS INITIATION
WITH CABLE GROUND EGRESS



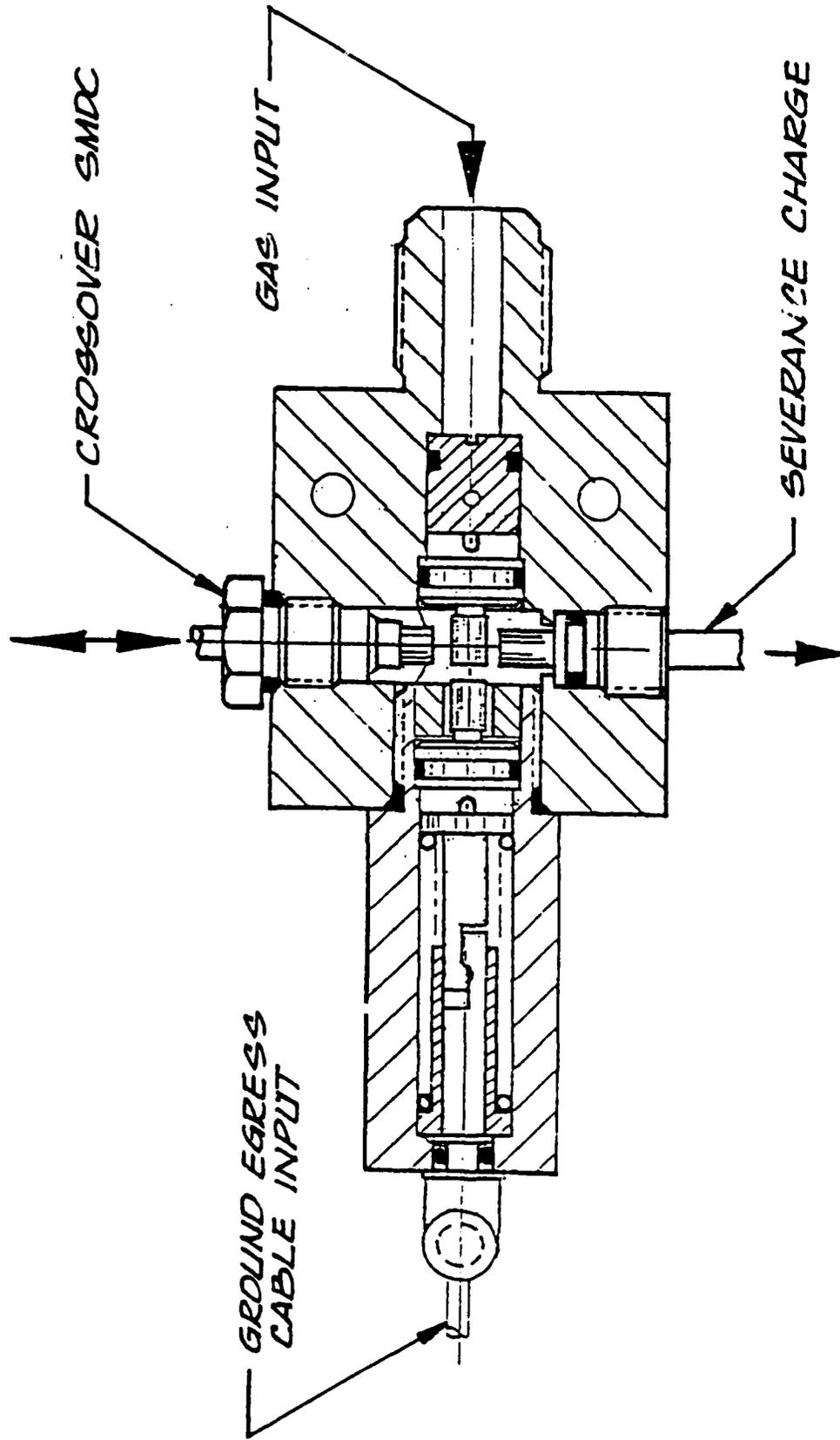


FIGURE 18
GAS ACTIATED DETONATOR

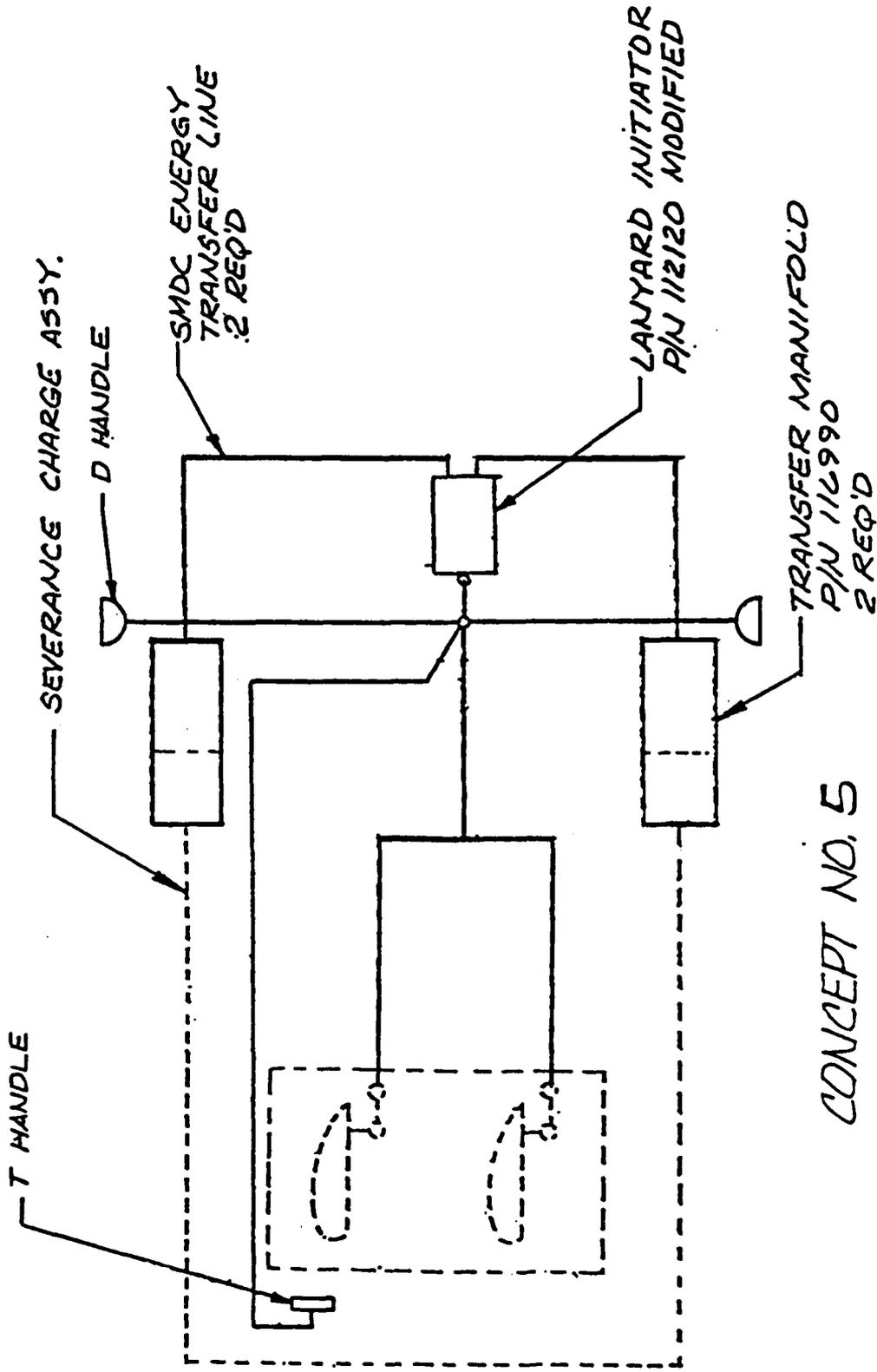


4.2 Concept Number 5 - Cable Initiation, Bulkhead Mounted

This design concept is shown on Figure 19. The concept utilizes control cables to initiate the system. In-flight egress is initiated when the seat mounted leg brace handles are actuated. Ground egress by the student pilot is initiated when the cockpit mounted T-Handle is actuated. Ground egress by the ground crew is initiated when either of the D Handles are actuated. Therefore, when the primary system inputs are actuated the Clear Path Egress System is also initiated. CPE ground egress can be made independent of the primary system by providing separate T&D Handles for actuating the Lanyard Initiator.

The cable attachment hardware for each input is shown on Figure 20. The hardware is designed to provide linear cable pulling motion when the M-27 Initiator is fired. Each of the inputs is connected by a cable to the Lanyard Initiator shown on Figures 21 and 22. When actuated the Initiator provides a detonation output to the SMDC energy transfer lines which are routed to the Transfer Manifolds (refer to Figure 11) which in turn initiate the severance charge. The Transfer Manifold was previously discussed in paragraph 4.1.1.1.

SPACE ORDNANCE SYSTEMS



CONCEPT NO. 5

FIGURE 19

CABLE INITIATION - BULKHEAD MOUNTED INITIATOR



24.

SPACE ORDNANCE SYSTEMS

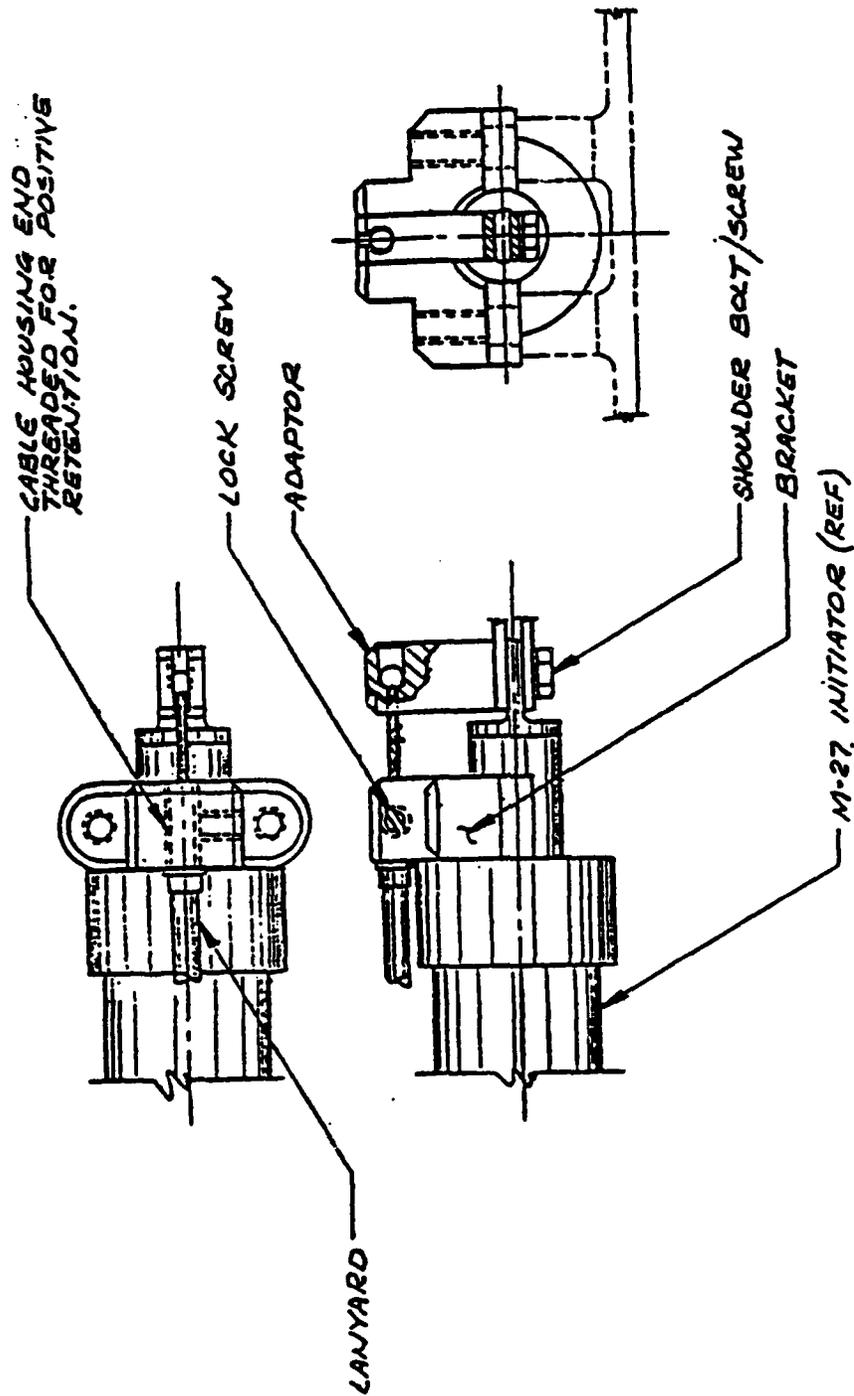


FIGURE 20
LANYARD ATTACHMENT
HARDWARE

SOS

INPUT: Pull force
OUTPUT: Detonation (BMDO)

Similar Items: 808 P/N's 112100, 112110, 112120 (F-14 Aircraft)
 114582, 114728 (Space Shuttle)
 115141 (AH-1B Helicopter)

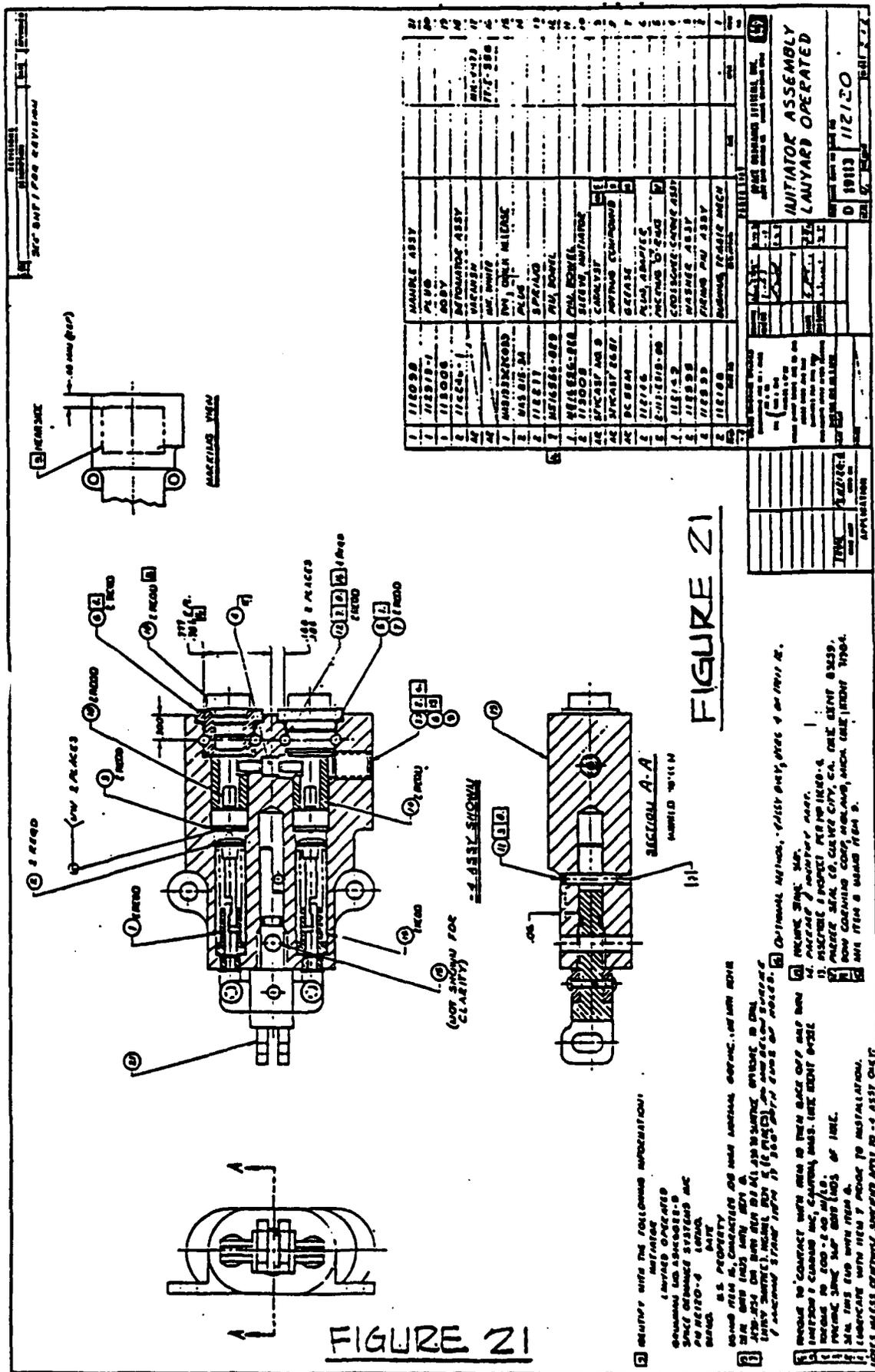


FIGURE 21

FIGURE 21

IDENTIFY WITH THE FOLLOWING INFORMATION:
 INITIATOR
 (INITIAL OPERATOR)
 SPACE ORANGE SYSTEMS INC
 10000 100TH AVE
 BIRMGHAM AL 35201
 205 963-1111
 205 963-1112
 205 963-1113
 205 963-1114
 205 963-1115
 205 963-1116
 205 963-1117
 205 963-1118
 205 963-1119
 205 963-1120
 205 963-1121
 205 963-1122
 205 963-1123
 205 963-1124
 205 963-1125
 205 963-1126
 205 963-1127
 205 963-1128
 205 963-1129
 205 963-1130
 205 963-1131
 205 963-1132
 205 963-1133
 205 963-1134
 205 963-1135
 205 963-1136
 205 963-1137
 205 963-1138
 205 963-1139
 205 963-1140
 205 963-1141
 205 963-1142
 205 963-1143
 205 963-1144
 205 963-1145
 205 963-1146
 205 963-1147
 205 963-1148
 205 963-1149
 205 963-1150

INITIATOR ASSEMBLY
 LAUNYARD OPERATED
 0 9913 112120

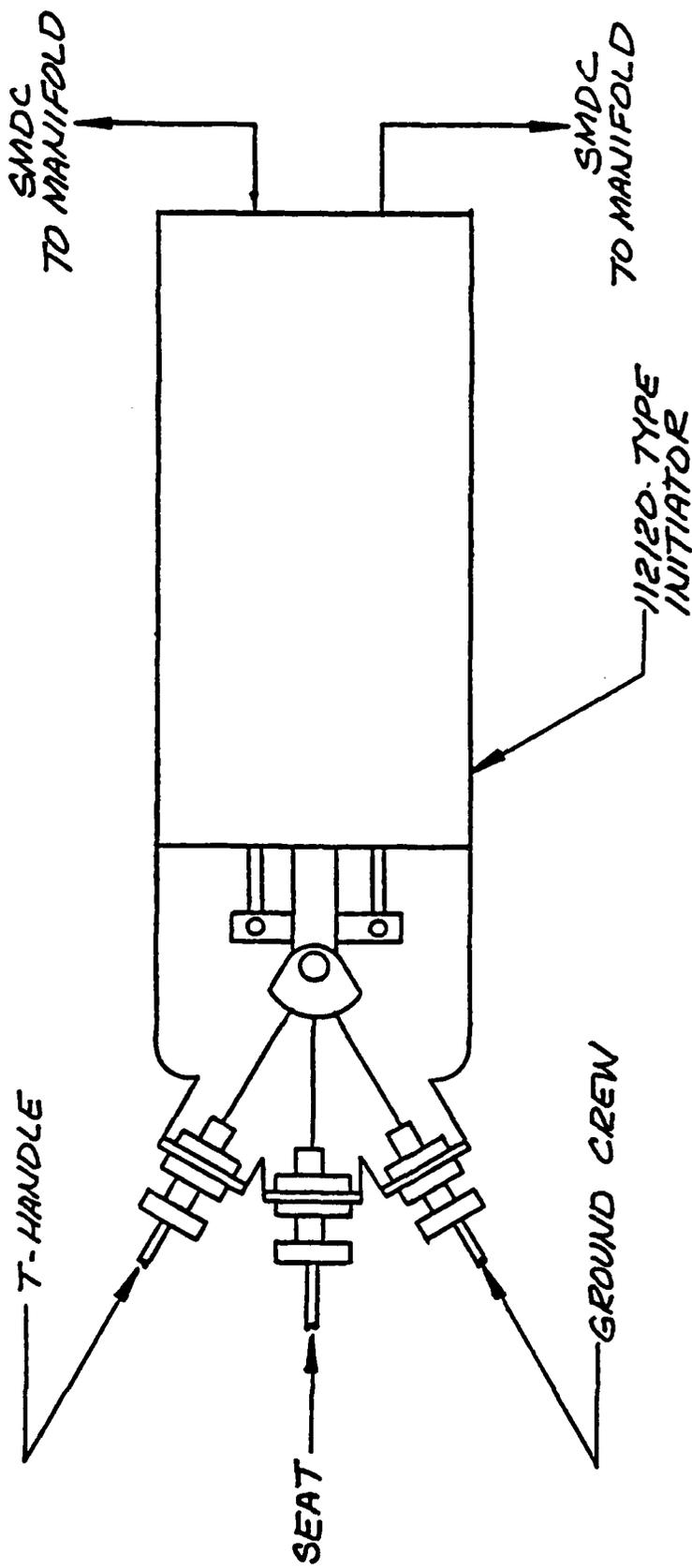


FIGURE 22
FOUR WAY INPUT



SPACE ORDNANCE SYSTEMS

4.2.1 Modifications

T-38 System modifications are as follows:

- Cable attachment kits must be installed on the seat mounted M-27 leg brace initiators. Cables must be adjusted. Seat must be removed for this modification.

T-38 Airframe modifications are as follows:

- Lanyard Initiator must be mounted to bulkhead behind seat.
- Cable Attachment kit must be installed on the T-Handle M-27 Initiator and cable routed to Lanyard Initiator while seat is out.
- Cable Attachment kits must be installed on the two D-Handle M-27 Initiators and cables routed to the Lanyard Initiator while the seat is out.
- Cockpit mounted half of the Transfer Manifold must be installed in the cockpit structure adjacent to the canopy.
- SMDC lines shall be installed from the Lanyard Initiator to the Transfer Manifold (2).



4.3 Concept Number 6 - Dual Cable Initiators - Canopy Mounted

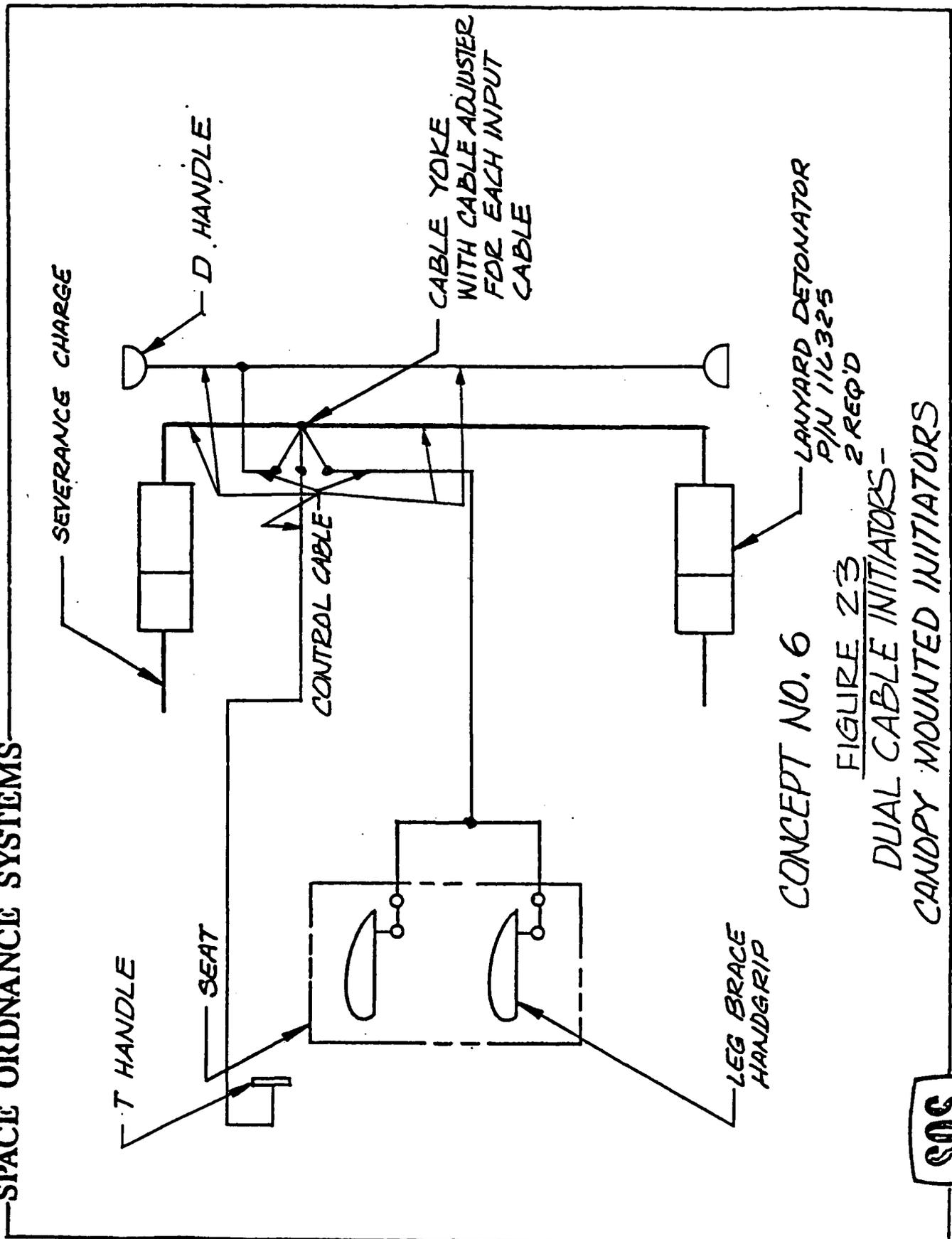
This concept is shown on Figure 23. The design, like concept number 5, utilizes control cables to initiate the system. Each of the primary system inputs for example, leg brace handles, D Handles and T Handle, when actuated, provides a linear pull force which fires the Detonator. Two Detonators as shown on Figures 24 and 25 are mounted on the Canopy. Flexibility of the control cables allow the canopy to be opened and closed without degrading functional performance.

All cable inputs are installed into a central Cable Yoke. A cable from each Detonator is installed into the output end of the Cable Yoke. All cables incorporate linear adjustment to assure that all cable slack can be eliminated.

CPE ground egress can be made independent of the primary system by providing separate T&D Handles for actuating the Lanyard Detonator.

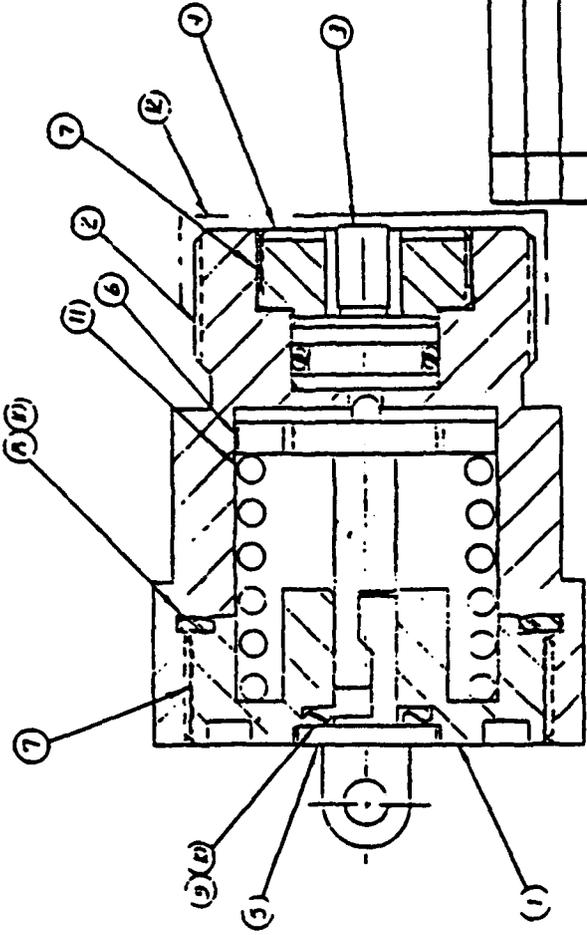


SPACE ORDNANCE SYSTEMS



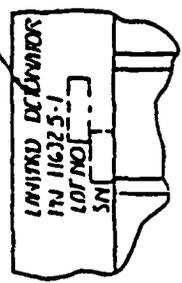
CONCEPT NO. 6
FIGURE 23
DUAL CABLE INITIATORS -
CANOPY MOUNTED INITIATORS
LAYNARD DETONATOR
P/N 116325
2 REQ'D

SOS



ELECTRO ETCH
 .06 HIGH CHARACTERS
 AS SHOWN

OUTFLEND



- NOTES:
1. ASSEMBLE AND INSPECT PER MP 116325-1
 2. PARKER SEAL CO, CULVER CITY, CALIF.
 3. LOH CORNING, MILLAND, MICH.
 4. IEE SPRING CO, BROOKLYN, NY.
 5. PROTECTIVE CLOSURES, WUFTLO, NY.
 6. LOCTITE CORP. NEWINGTON, CONN.

REV	DATE	DESCRIPTION	BY	CHKD
1	10/15/56	INITIAL DESIGN
2	11/15/56

QTY	PART NO.	DESCRIPTION	SIZE	SPEC	ITEM NO.
1	EC-16	CAPLUG			15
1	LC-053J-2 MAX	SPRING			14
AR	LC-35M	GREASE			13
1	1-009, E315-80	ORING			12
1	2-010, E315-80	O RING			11
AR	GR AA	LOCTITE 242			10
1	116257-1	FIRING PIN			9
1	116209-1	SEAR			8
1	116259-1	PRIMER PLUG			7
1	116277-1	DETONATOR ASSY			6
1	116254-1	BODY			5
1	116236-1	RETAINER			4

SPACE ORDNANCE SYSTEMS
 116325

LANYARD DETONATOR

SCALE 4/1

116325

C 19113

116325

FIGURE 24

4.3.1 Modifications

Modifications to the T-38 System are as follows:

- Cable Attachment kits must be installed on the seat mounted M-27 leg brace initiators. Cables must be adjusted. Seat must be removed for this operation.

T-38 Airframe modifications are as follows:

- Cable Yoke must be installed on bulkhead behind seat, while seat is removed.
- Cable Attachment kit must be installed on the "T"-Handle M-27 Initiator and cable routed to Cable Yoke while seat is removed.
- Cable Attachment kit shall be installed on both "D" Handle M-27 Initiators and cable routed to Cable Yoke.
- Cable Yoke output cables shall be installed in the two canopy mounted Detonators after canopy is installed.
- All cables shall be adjusted to eliminate slack.



SPACE ORDNANCE SYSTEMS

5.0 REVIEW OF CANOPY SEVERANCE AND REMOVAL DESIGN CONCEPTS

This section describes the concepts developed for the T-38 program which are considered feasible for implementation.

Criteria for concept selection is as follows:

- Clear out escape route for air crew member
- Reduction of pre-ejection time delay
- Minimize T-38 modification
- Minimize ground egress time delay
- Consideration of injury to air and ground crew
- No degradation of primary ejection system
- Compatibility with T-38 airframe and systems
- Reliability
- No scheduled maintenance
- Function after bird strike

Each of the proposed concepts require a back up for removing the canopy after it has been released (severed) from the aircraft. Two potential concepts are proposed, canopy mounted rocket motors and a seat mounted canopy pushing structure. Each of these concepts will be aided by the aerodynamic lift and loads imposed on the transparency after it has been lifted into the airstream. Figure 26 illustrates the canopy position at which aerodynamic assist will occur. The amount of aero assist in removing the canopy depends entirely on aircraft



AT 8°30' CANOPY ROTATION THE ENTIRE FORWARD EDGE IS ABOVE THE WINDSHIELD. IT IS ASSUMED THAT AT THIS POSITION AERODYNAMIC LIFT WILL PROVIDE CANOPY REMOVAL FORCE.

SEAT CATAPULT DATA: 8°30' ROTATION IS EQUAL TO 2.9 INCHES OF CATAPULT STROKE OR 12.1% OF THE TOTAL 24 INCH STROKE BEFORE STRIPOFF

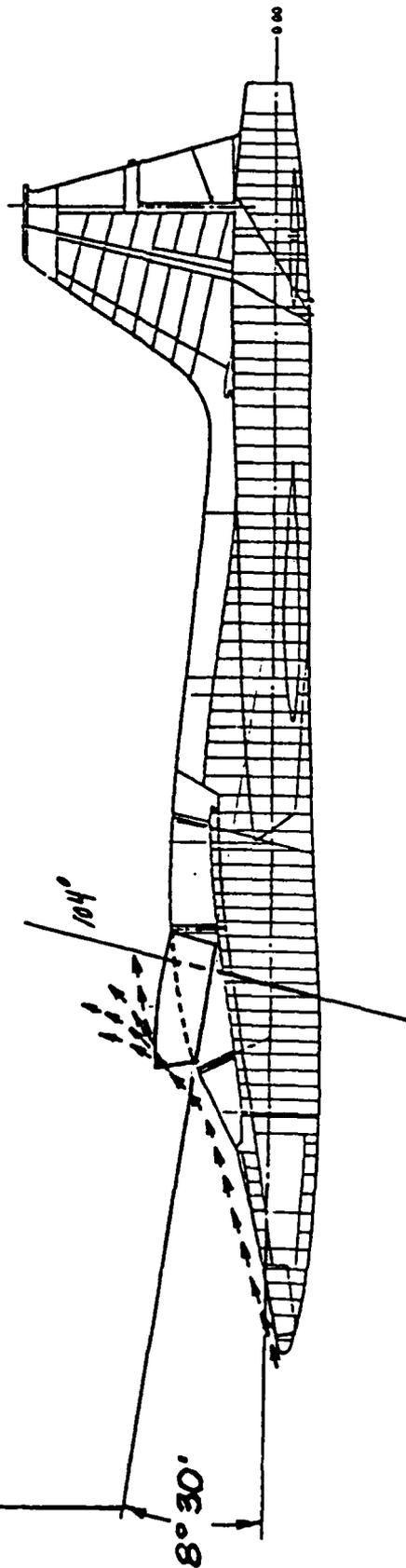


FIGURE 26

5.0 REVIEW OF CANOPY SEVERANCE AND REMOVAL DESIGN CONCEPTS

speed, but at ejection speeds the total energy required for canopy removal is substantially lower than that for the static condition. Performance analysis for the seat mounted pushing structure and canopy mounted rocket motor concepts in the following paragraphs does not include aerodynamic assistance.

5.1 Explosive Cord Configuration

5.1.1 Surface Mounted

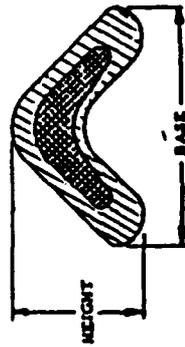
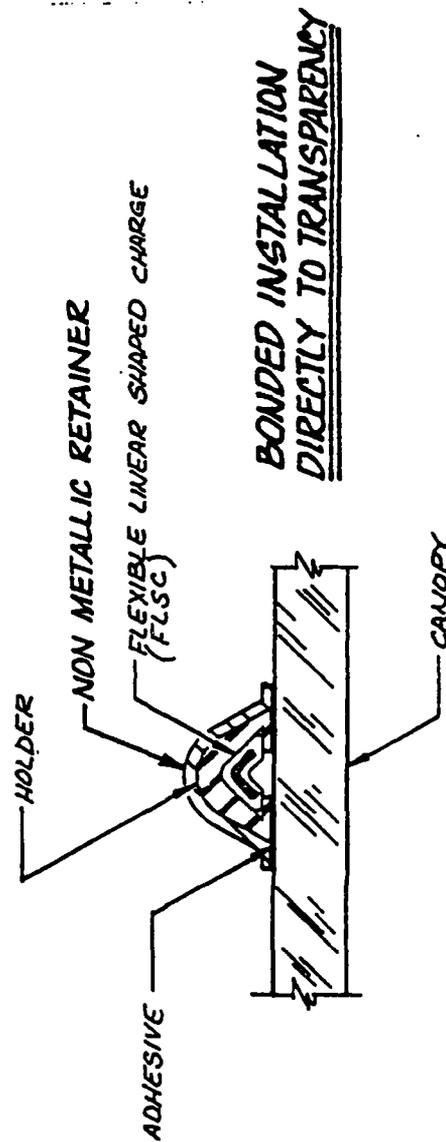
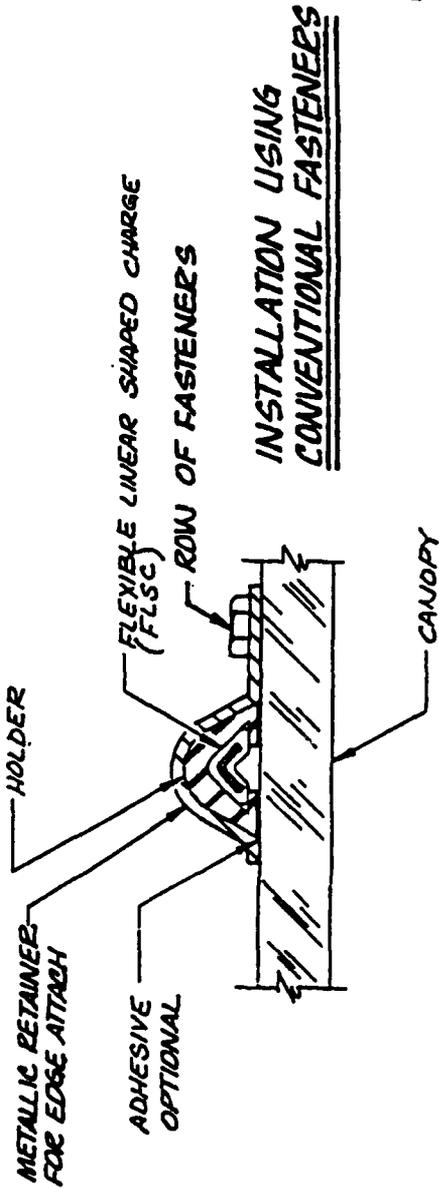
FLSC is considered to be more suitable than MDF for the T-38 application when the explosive cord is mounted on the polycarbonate transparency surface. Therefore FLSC is the primary candidate. Figure 27 illustrates the typical installation as well as size versus core load data.

5.1.2 Edge Imbedded

For concepts utilizing edge imbedded explosive cord the round cross section of MDF is ideal. Therefore MDF is the primary candidate for concepts which incorporate the edge imbedded MDF technique.



SPACE ORDNANCE SYSTEMS



LOAD GR/FT	TABULATION		WEIGHT LB/FT
	BASE IN.	HEIGHT IN.	
5	.14	.07	.01
7	.14	.07	.02
10	.16	.09	.02
15	.20	.11	.03
20	.21	.12	.04
25	.24	.13	.05
30	.25	.15	.06
40	.28	.17	.08
50	.33	.20	.09
65	.34	.21	.10
75	.36	.23	.11
100	.43	.24	.15
125	.48	.29	.23
150	.49	.30	.30
175	.55	.33	.32
200	.58	.35	.37
250	.64	.39	.44
300	.73	.47	.54
400	.88	.54	.75

Lead Sheathed Linear Shaped Charge

FIGURE 27
FLSC SEVERANCE CHARGE



5.2 Concept A - Overhead Panel Cut/Seat Mounted Pusher

This concept is illustrated on Figure 28. The overhead panel cut is of sufficient width to allow ejection without contacting the canopy side sections left intact with the canopy frame. At the rear of the canopy a panel hinge section is left unsevered. This section provides a hinge point which controls the panel cut out while it is pushed up and out of the ejection envelope path by the seat mounted pushing surface. A sub scale layout verifies that the cut out section will be free to rotate through the required arc with no mechanical interference.

When combining the cutting effects of FLSC with the laminated or monolithic polycarbonate there will be no transparency fragmentation sufficient to cause permanent injury.

The major constraining feature for this severance pattern is that side vision is somewhat impaired by the severance charge and ancillary hardware.

Another constraint is that splatter shielding is less effective since a rigid metallic shield can not be positively retained in the canopy sides without degrading the bird resistance of the canopy. For this reason the potential of injury due to metallic sheath splatter (fragment hazard) is higher than any of the other concepts.

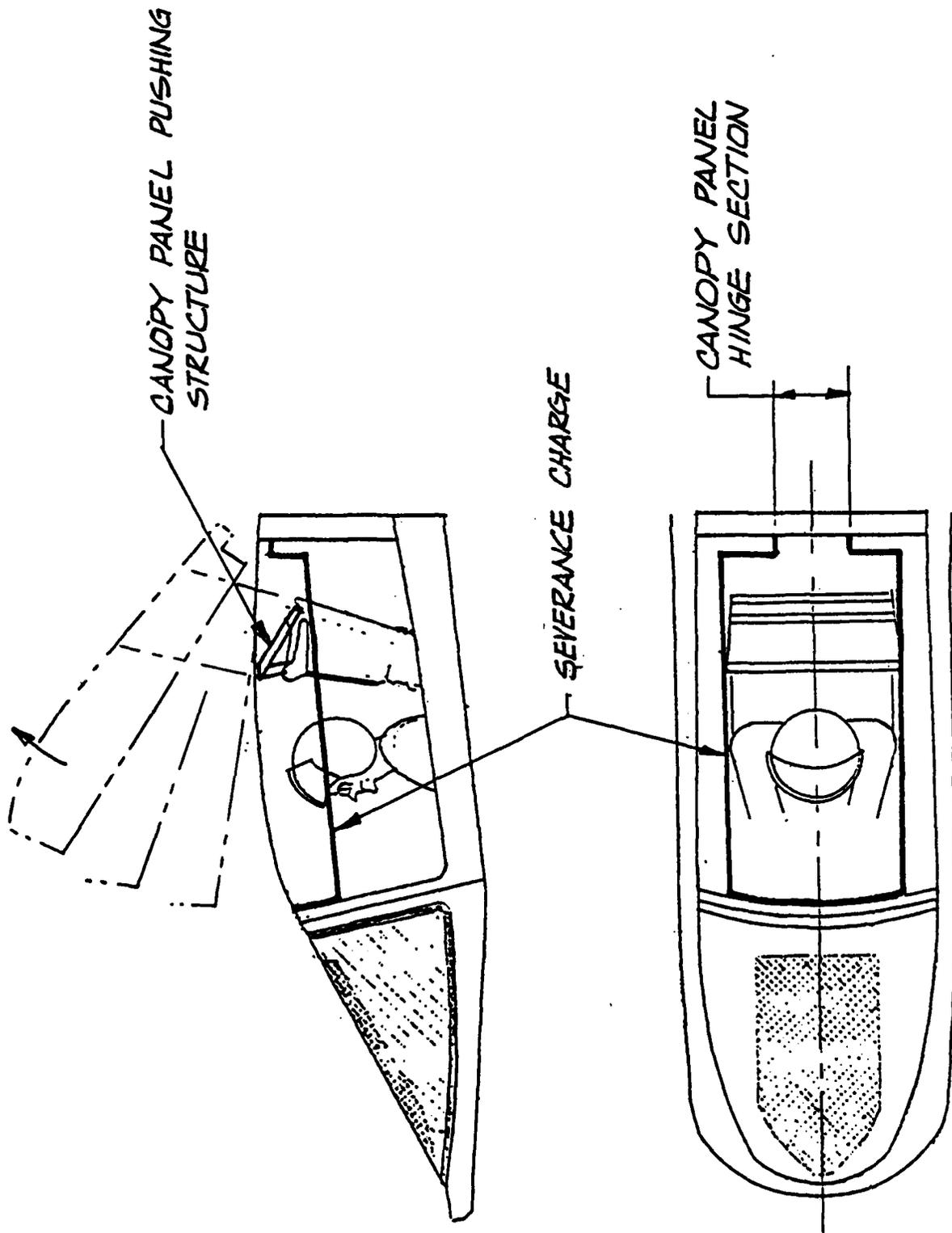


5.2 Concept A - Overhead Panel Cut/Seat Mounted Pusher
(Continued)

Cutting efficiency of the FLSC severance charge is dependent on the standoff air gap between the charge and the target material. The reliability of the concept defined herein is based on the capability of maintaining the required charge and target air gap standoff after a bird strike occurrence. Therefore, reliability translates to the method of attaching the charge to the canopy. If the charge is retained adhesively, it is clear that the functional capability is dependent on the strength and flexibility of the adhesive. Impact shock and resultant waves emanating from the bird impact zone, could, if sufficient, separate the severance charge from the canopy. It would appear that a bonded joint is feasible, but attention is necessary in selecting a charge retainer material and adhesive which is totally compatible with the polycarbonate transparency material. This however should not present a problem since adhesive technology is quite capable of assuring the intimate proximity of the FLSC charge to the transparency. A thorough study, test and analysis program would be essential prior to incorporating a bonded severance charge.

Vision from the rear cockpit can be maintained by contouring the canopy panel pushing structure to mate with the canopy internal surface.





CONCEPT A

FIGURE 28

PANEL SEVERANCE WITH PUSHER

5.2 Concept A - Overhead Panel Cut/Seat Mounted Pusher
(Continued)

Weight of the pushing structure is estimated at 5 pounds maximum. Since the variation from pilot to pilot has no effect on seat performance it is reasonable to assume that the pusher will not degrade seat performance or alter seat stability in any manner. Drogue chute capability is provided within the seat to assure stability of the seat - man during ejection.

EJECTION SEAT PERFORMANCE

It is anticipated that this concept will require initial catapult energy to force the severed canopy up into the airstream during ejection. The seat contains a CKU-7 catapult which pushes the seat up out of the cockpit. The seat also contains a rocket motor which propels the seat-man further up and away from the aircraft. The rocket motor is ignited when catapult stripoff occurs. Position of the canopy at catapult stripoff is shown on Figure 29. Figure 30 provides catapult and rocket motor performance requirements and actual performance test data obtained from Hill Air Force Base.

During ejection from the T-38 aircraft under nominal conditions, catapult thrust increases in a nearly linear fashion from 0 to approximately 5,000 lb. Since the stroke of the catapult is about 2 ft, the work done on the seat/man mass is



5.2 Concept A - Overhead Panel Cut/Seat Mounted Pusher
(Continued)

between 5,000 and 10,000 ft lb. A second approximation to the work done by the catapult comes from equating it to the kinetic energy of the seat/man at the time of catapult strip-off. Typical velocity for a 460 lb seat/man at catapult strip-off is 40 ft per sec corresponding again to about 10,000 ft lb of energy (work).

Aerodynamic loading on the canopy is unknown at this time. Based on the primary canopy jettison system we must assume that minimal energy is required to overcome the aero loading in the canopy. However, to analyze seat performance a worst case value of 150 foot pounds is assigned to overcome the aero loading on the canopy. An additional 150 foot pounds worst case is estimated for lifting the canopy up through the aero load region into the aerodynamic lift zone. The total catapult work required then is 300 foot pounds maximum which represents 3% of the available catapult energy. The McCarty-Smith T-38 Canopy MAGNA analysis estimates a maximum of 120 foot pounds catapult energy is required to penetrate the existing T-38 canopy during TTC ejection. Based on the above, no significant seat performance degradation would be expected as a result of the work required to lift the canopy as required to clear the ejection path.



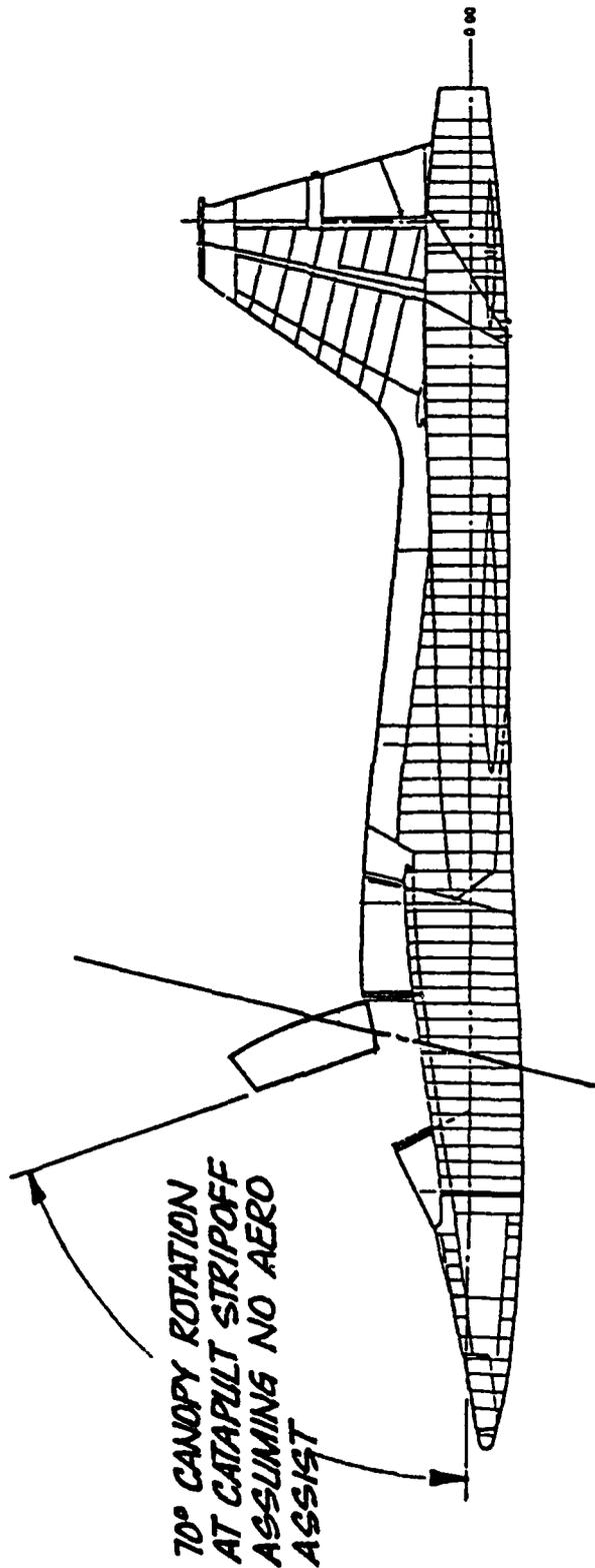


FIGURE 29

PARAMETER	SPECIFICATION PERFORMANCE		ACTUAL PERFORMANCE	
	AT -65°F	AT +165°F	AT -65°F	AT +165°F
<u>Catapult</u>				
Ignition Time	30 MS Max	30 MS Max	19/27	18/26
Thrust	7000 lbs max	7300 lbs max	4017/4426	6629/7005
Acceleration	20 g max	20 g max	7.9/8.7	13.2/14.0
On Set Acceleration	300 g/sec max	300 g/sec max	70/84	116/139
Velocity At Strip Off	36 ft/sec min	42 ft/sec min	37.6/39.0	47.6/48.5
Launch Time (Ign. to Strip Off)	210 ms max	200 ms max	176/194	145/161
<u>Seat Rocket Motor</u>				
Ignition Time (After Strip Off)	25 ms max	25 ms max	4	4/6
Thrust	7350 lbs max	7600 lbs max	3265/3572	4240/4696
Burn Time	550 ms max	465 ms max	430/480	317/372
Impulse	1100 lb sec	1100 lb sec	1282/1333	1298/1334

- NOTES: 1. All tests conducted using 460 lbs seat/man mass.
2. Input pressure from pneumatic source
WAS: 317/372 PSI for low temp tests
258/292 PSI for high temp tests
3. Data obtained from Mr. Don Burton, Equipment Engineer,
Hill Air Force Base.

FIGURE 30

CKU-7 CATAPULT PERFORMANCE
CHARACTERISTICS

5.3 Concept B - Perimeter Severance With Seat Mounted Pusher

This design is shown on Figure 31. The concept utilizes a full perimeter FLSC transparency cut and a seat mounted pushing surface to push the canopy up and out of the ejection path.

This configuration causes insignificant vision impairment of the student pilot due to the edge attached FLSC surface mounted and ancillary hardware. Further, the edge attached FLSC allows the use of a high strength splatter shield which should preclude injury due to FLSC sheath splatter.

At the rear of the canopy a hinge section is left intact to provide a hinge point. The hinge provides a pivot point which guides and controls the severed transparency while it is pushed up and out of the ejection path. A sub-scale layout verifies that the cut out section will be free to rotate through the required arc without mechanical interference.

The inherent strength of the polycarbonate combined with the transparency stiffness and freestate contour will prevent the canopy from collapsing inward or wrapping around the pilot during the jettison function.

The seat catapult energy required to remove the severed canopy will be the same as that required for concept A. Therefore, no seat performance degradation is expected.



SPACE ORDNANCE SYSTEMS

5.3 Concept B - Perimeter Severance With Seat Mounted Pusher

When analyzing ejection with full perimeter severance concept it is necessary to review what takes place when the primary and CPE initiation systems both function in a proper manner. What takes place in this situation for initiation concepts 1, 2, 3 and 4 is different than that for concepts 5 and 6. With concepts 1, 2, 3 and 4 a 0.3 second time delay is provided between primary system initiation and catapult ignition - CPE system initiation. This 0.3 seconds allows the canopy to jettison before the seat is ejected and before the CPE system is initiated. With concepts 5 and 6, the CPE system is initiated simultaneously with primary system initiation. However, the 0.3 second time delay would still be maintained for the catapult ignition function.

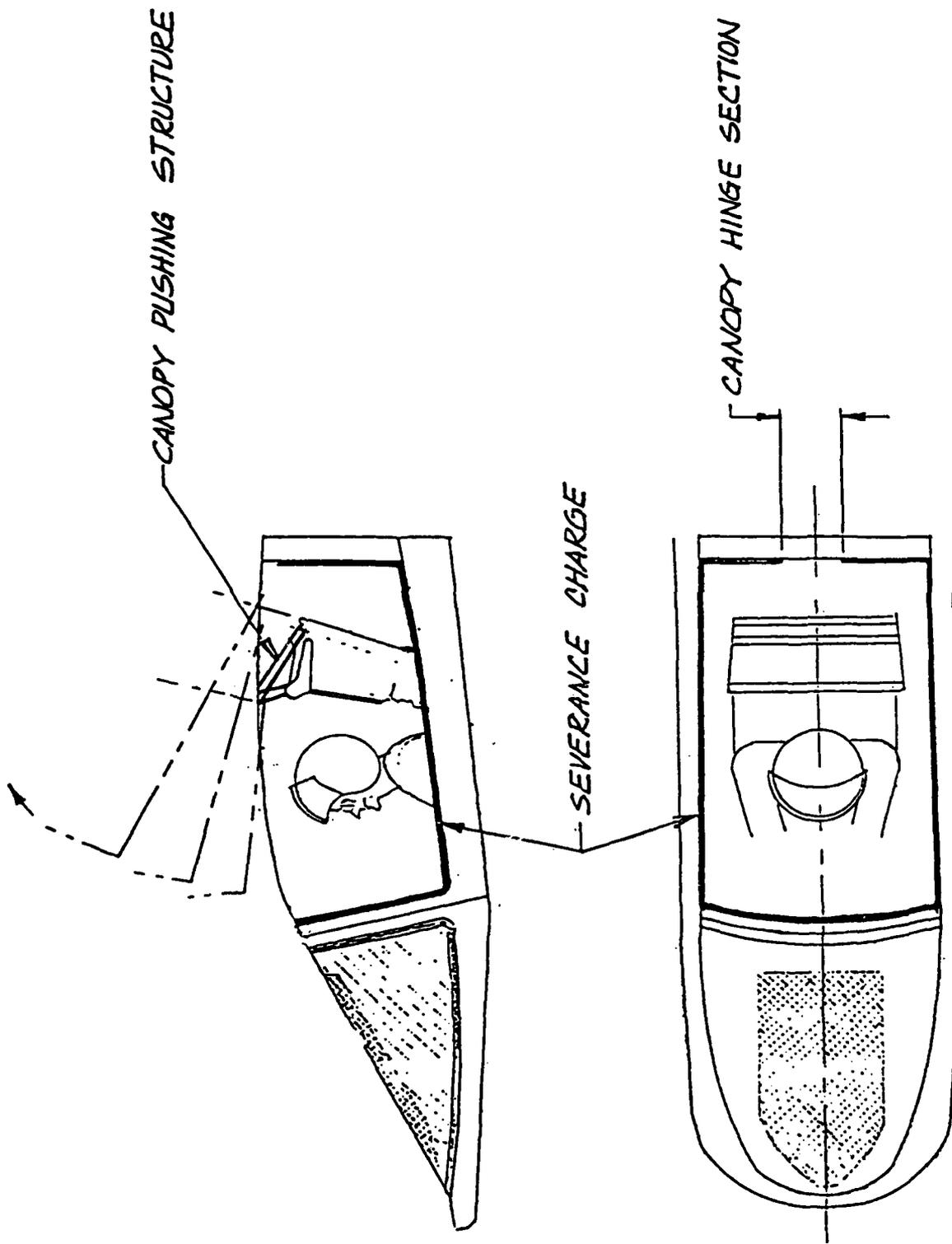
Next let us look at what happens to the canopy frame and severed canopy if the CPE and primary system actuates the canopy jettison thrusters and the canopy is thrust up and out of the ejection path. CPE initiation concepts 1, 2, 3 and 4 are initiated 0.3 seconds after canopy jettison and since the canopy is already away from the aircraft the CPE system function is eliminated. With concepts 5 and 6 the canopy jettison and transparency severance functions occur simultaneously. Since the transparency is attached to the canopy frame by the trans-



5.3 Concept B - Perimeter Severance With Seat Mounted Pusher

parency rear hinge section, the frame and transparency will be jettisoned intact in the normal manner. Some reduction in aerodynamic lift efficiency will be lost, but the canopy jettison thrusters are designed to function when unassisted aerodynamically.





CONCEPT B

FIGURE 31

PERIMETER SEVERANCE WITH PUSHER

5.4 Concept C - Perimeter Severance With Canopy Mounted Rocket Motors

This design is illustrated on Figure 32. The concept utilizes the full perimeter severance technique combined with canopy mounted rocket motors to remove the severed canopy.

The canopy severance is identical to that described for Concept B in paragraph 5.3.

Canopy jettison is provided by two solid propellant rocket motors which are mounted in the forward lower corners of the canopy transparency. Rocket motors are presently used for canopy jettison on the F-16 and F-18 aircraft and therefore the technology and components already exist.

Ignition of the solid propellant rocket motors can be achieved with the FLSC Severance Charge. The F-16 and F-18 rocket motors are ignited using Detonating Transfer Assemblies. Therefore a suitable interface between the FLSC and the rocket motors presents no technical risk.

The potential of injury in the form of rocket blast burns should be considered the major constraint. The forward cockpit of the T-38 was not designed for this application and the rocket blast will be virtually in the student pilots lap. However, it is feasible that blast deflectors can be designed



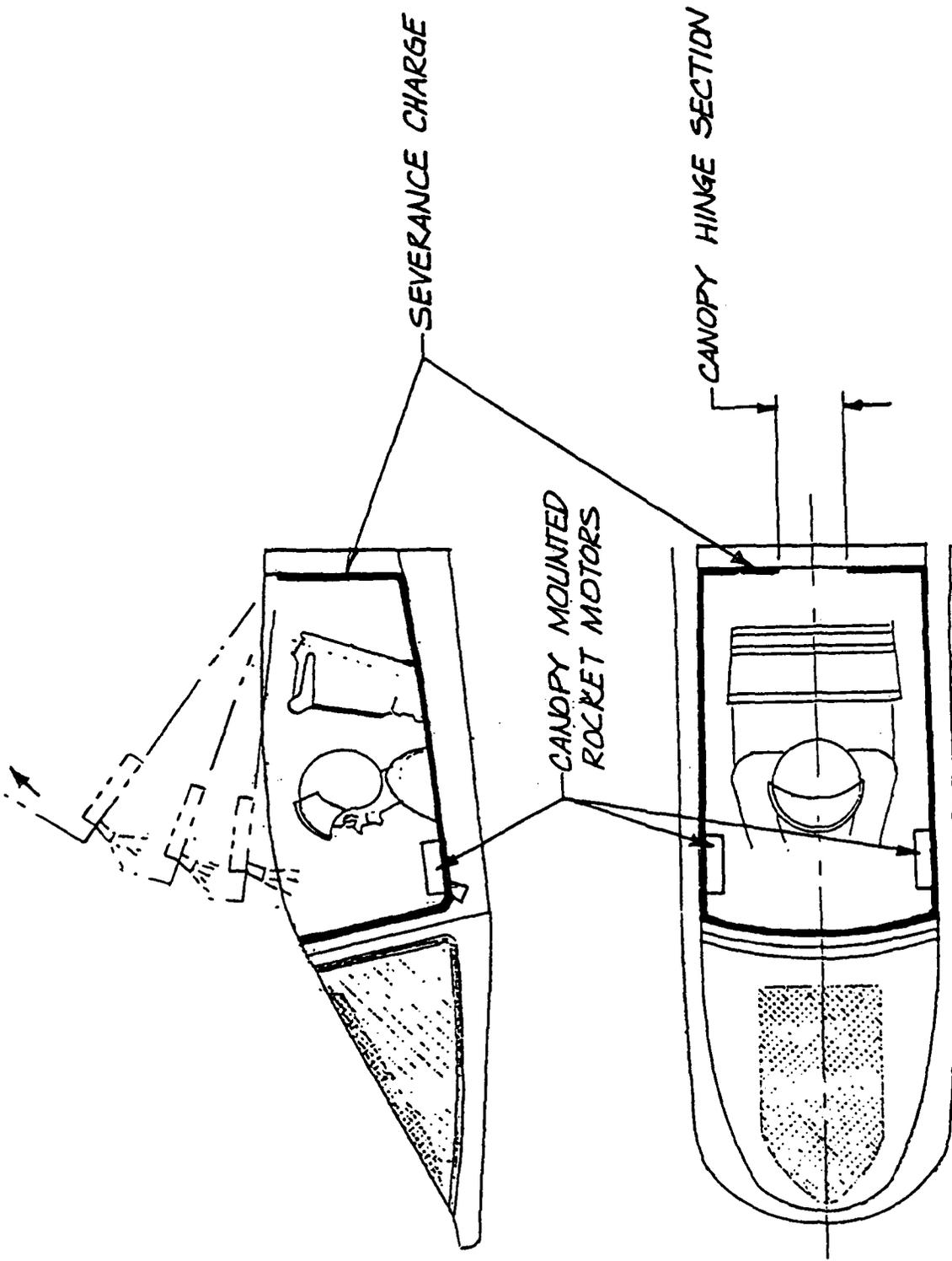
5.4 Concept C - Perimeter Severance With Canopy Mounted Rocket Motors (Continued)

which would significantly reduce this hazard. This requires additional study testing and analysis prior to implementing this concept into the T-38 program.

Added canopy weight is another consideration associated with canopy mounted rocket motors. It is known that minimum weight added to the canopy is desirable. The total weight addition will be 5.0 pounds since each F-18 rocket motor weighs 2.50 pound. Dimensions of the rocket motor are 1.54 dia x 11.94 length.

If Concept C is combined with the Gas Initiation Concepts 1, 2 or 3 the gas takeoff location must be between the M-27 Initiator and the 0.3 Second Time Delay Initiator. This will allow 0.3 seconds for jettison of the canopy before ejection. Without this time delay the rocket motors may not clear the canopy from the ejection path, resulting in canopy/seat collision and potential student pilot injury.





CONCEPT C

FIGURE 32

PERIMETER SEVERANCE WITH ROCKET MOTORS

5.5 Concept D - Centerline Severance With Seat Mounted Parting Structure

This configuration is shown on Figure 33. This design concept provides a full length cut down the centerline of the canopy along with forward and aft edge cuts down to the side sill on each side of the canopy. The two severed halves of the canopy are retained by the side sill edge attach which runs the full length of the transparency. Each side sill edge attach acts as a hinge which controls each half of the canopy. Each side sill edge attach also provides a pivot point for each canopy half.

A parting structure is mounted on the seat which forces the canopy open when the seat is ejected through the interface plane. The side sill edge technique will have an effect on the energy required to separate the two canopy halves. If a rigid "bolt through" design is incorporated into the sill attachment then the edge attach must be structurally yielded to provide an adequate ejection envelope. The available catapult energy is sufficient to yield any conceivable edge sill attachment concept the required amount to provide seat-man clearance between the two canopy halves. As stated in the ejection seat performance discussion of Paragraph 5.2, the available catapult energy is 10,000 pounds under nominal conditions. It is inconceivable that more than 500 foot pounds



5.5 Concept D - Centerline Severance With Seat Mounted Parting Structure (Continued)

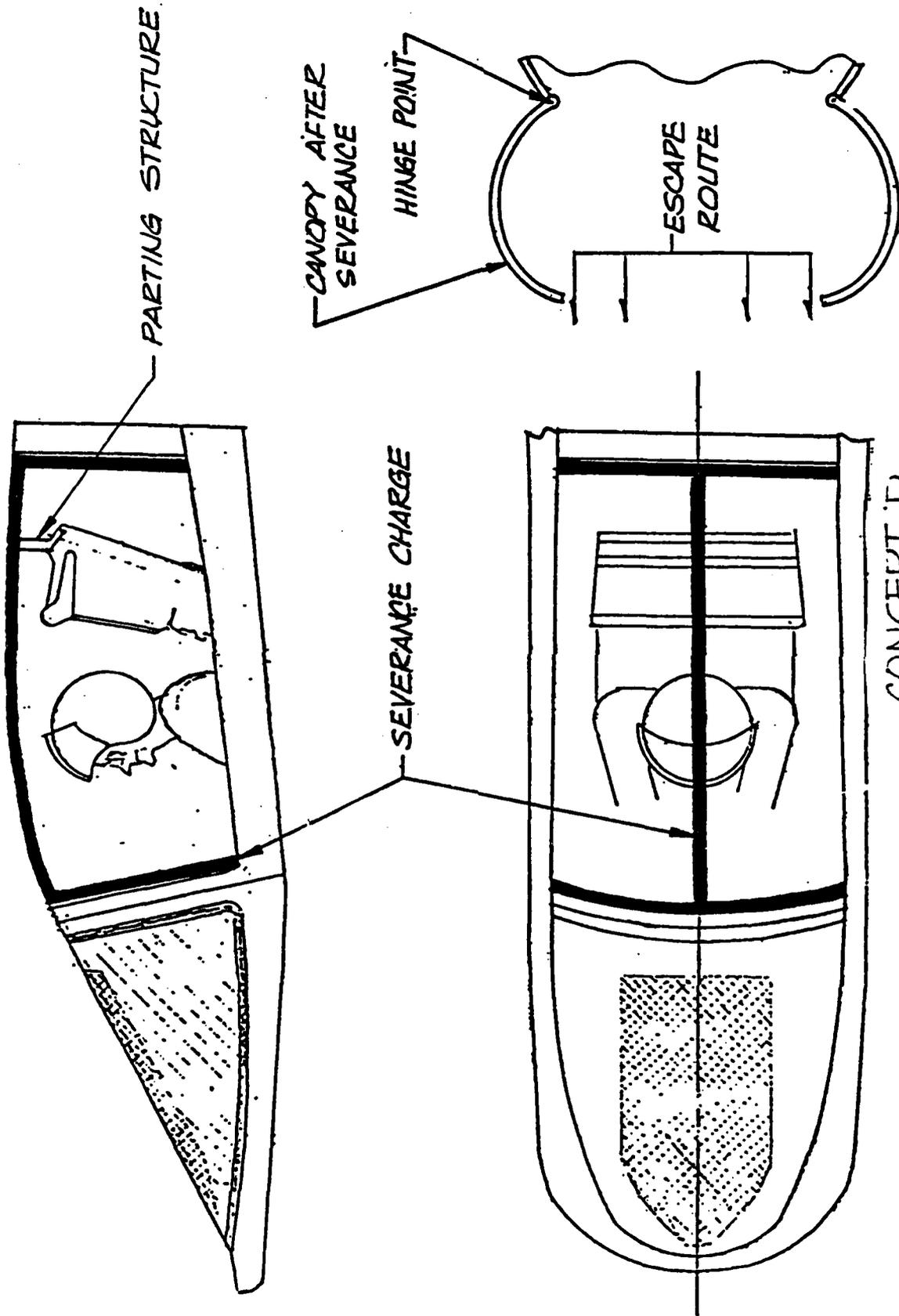
(5% of nominal catapult energy) would be required to bend sheet metal side edge attach members. However, attention to design is required to allow the side edge member to bend in an arc sufficient for the required escape envelope.

Potential ejection seat performance degradation would be insignificant since a maximum 5% of the total catapult energy is required to separate the two halves of the canopy. The actual seat performance would be degraded by 5% maximum of the catapult performance. But the rocket motor output would not be degraded. It is worthy of mention that all energy to separate the canopy halves would be applied in the first half of the catapult stroke prior to strip off, thus assuring the available energy input to the edge side members.

For in-flight ejection a metallic or plastic hand guard should be added to the outboard side of each leg brace handle. This is considered necessary to preclude hand contact with the canopy halves during ejection.

Student pilot overhead vision is somewhat impaired by the single strand of severance charge running along the canopy centerline. Instructor pilot forward vision is also impaired slightly by the centerline charge. The expected width of the FLSC, retainer and splatter shield will not exceed .625 inch.





CONCEPT D
 FIGURE 33

CENTERLINE SEVERANCE WITH SEAT
 MOUNTED PARTING STRUCTURE

5.5 Concept D - Centerline Severance With Seat Mounted Parting Structure (Continued)

Functional capability of the centerline charge after bird strike is dependent on the strength and flexibility of the bond if the charge is retained adhesively. Impact shock and resultant waves emanating from the bird impact zone, could, if sufficient, separate the severance charge from the canopy. It would appear that a bonded joint is feasible, but attention is necessary in selecting a charge retainer material and adhesive which is totally compatible with the polycarbonate transparency material. A thorough study, test and analysis program would be essential prior to incorporating a bonded centerline severance charge.

5.6 Concept E - Side and Rear FLSC Severance With Seat Mounted Pusher

This design is shown on Figure 34. The concept utilizes FLSC to cut the forward former, side edge attach plates and the rear of the transparency except for the hinge section. A seat mounted pushing structure as in concepts A, B and D is utilized to push the canopy up and out of the ejection path.

As in all previously discussed concepts a hinge section is left uncut to guide and control the severed transparency as it rotates up and out of the ejection path.



5.6 Concept E - Side and Rear FLSC Severance With
Seat Mounted Pusher (Continued)

This concept utilizes surface mounted FLSC wherein a high strength retainer is utilized. Therefore, adhesive is not required for holding the FLSC in position. Use of the retainer also protects the student pilot from splatter.

This concept has the advantage that no structure or transparency cutting is accomplished directly in front of the student pilot. Further, all spalled debris will be directed outward away from the student pilot. This precludes the possibility of injury as a result of debris and splatter.

Another advantage with the concept is that the noise level will be minimal since the length of FLSC is reduced from that of concepts A, B, C and D. The length of FLSC required to run up and over the front arch of the transparency is eliminated, thereby substantially reducing the length of FLSC required to release the transparency.

Vision will be unaffected with this concept since all hardware will be mounted below the canopy structure.



CANOPY PUSHING STRUCTURE

FLSC SEVERANCE CHARGE CUTS TRANSPARENCY REAR QUADRANTS

FLSC SEVERANCE CHARGE CUTS EDGE ATTACH PLATES & FORWARD FORMER

CANOPY HINGE SECTION

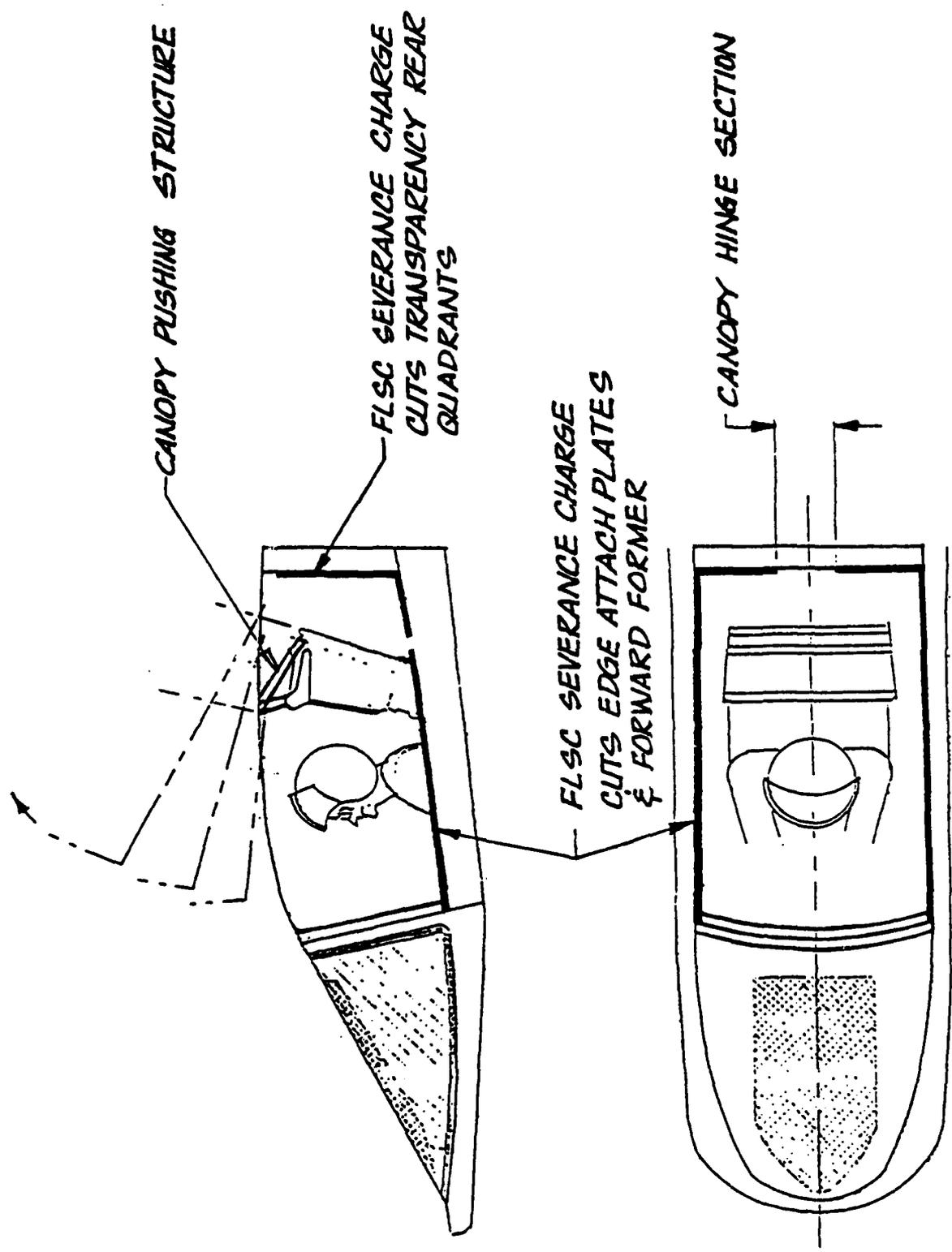


FIGURE 34
CONCEPT E
 SIDE & REAR FLSC SEVERANCE
 WITH SEAT MOUNTED PUSHER

5.7 Concept F - Side and Rear Severance Using Edge Imbedded MDF With Seat Mounted Pusher

This design is shown on Figure 35. The concept severs the sides and rear arch of the transparency (except for hinge section). The forward former is cut on each side at the sill level. The seat mounted pushing structure is used to push the transparency up and out of the ejection path.

Edge imbedded MDF is utilized to sever the sides and rear of the transparency. Installation for this technique is shown on Figure 4A and discussed in Paragraph 3.4.1. The MDF will terminate in the forward former charge retainer blocks. Charge retaining blocks are mounted at the foot of the forward former on each side of the canopy. This block houses the former cutting charge and will provide splatter shield capability. With this concept no structure or transparency cutting is accomplished directly in front of the student pilot. Further, all spalled debris will be directed outward away from the student pilot. This precludes the possibility of injury as a result of debris and splatter.

The noise level will be minimal since the length of FLSC is reduced from that of concepts A, B, C and D. The length of FLSC required to run up and over the front arch of the transparency is eliminated, thereby substantially reducing the length of FLSC required to release the transparency.

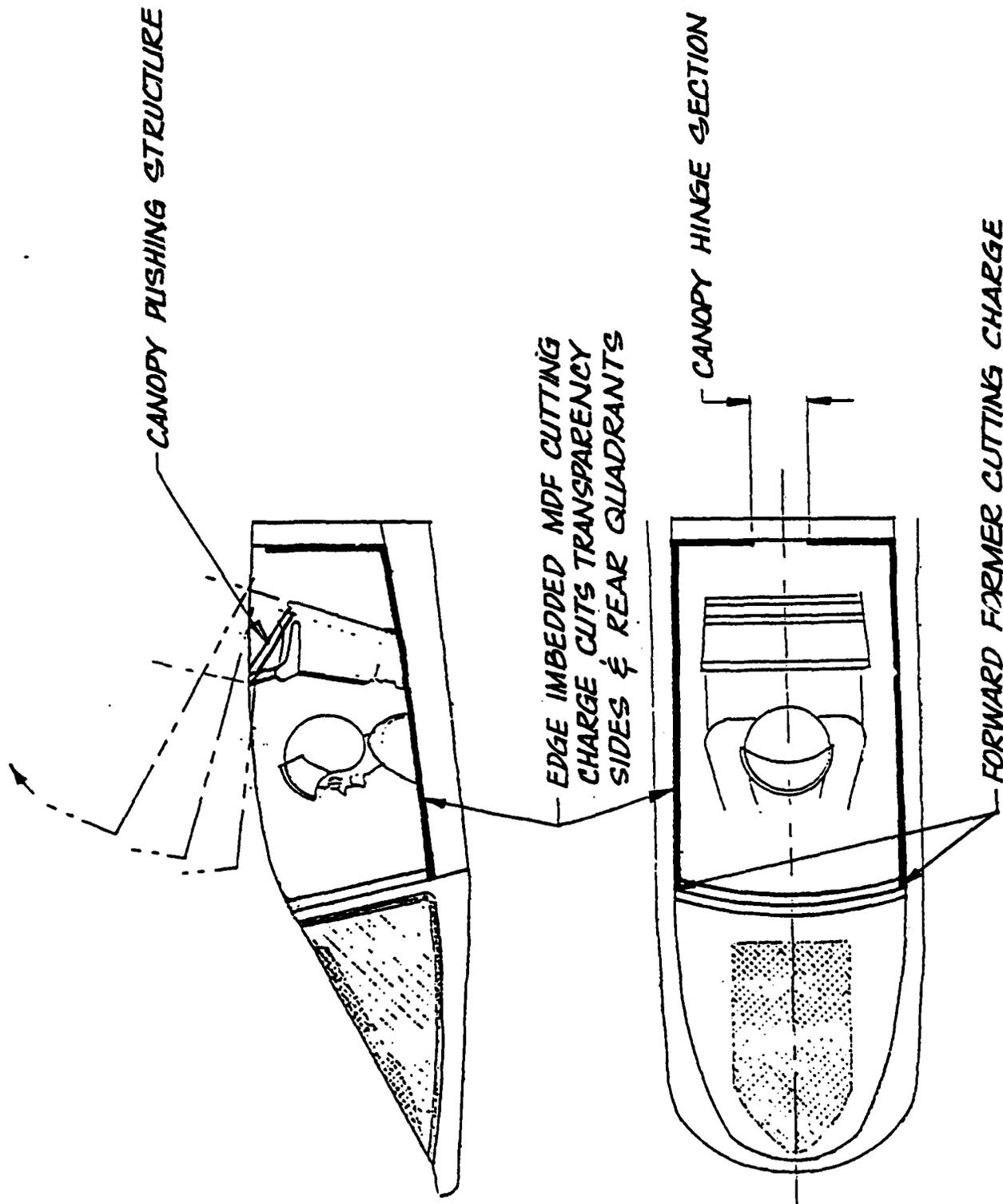


5.7

Concept F - Side and Rear Severance Using Edge
Imbedded MDF With Seat Mounted Pusher (Continued)

Pilot vision will be unaffected with this concept since all hardware will be mounted below the canopy structure.





CANOPY PUSHING STRUCTURE

EDGE IMBEDDED MDF CUTTING CHARGE CUTS TRANSPARENCY SIDES & REAR QUADRANTS

CANOPY HINGE SECTION

FORWARD FORMER CUTTING CHARGE INITIATED BY MDF CUTS FORWARD FORMER

CONCEPT F

SIDE & REAR SEVERANCE USING EDGE IMBEDDED MDF WITH SEAT MOUNTED PUSHER

6.0 CONCEPT EVALUATION

6.1 Evaluation

Two sets of evaluation criteria were established for ranking the initiation concepts. Primary elements along with several supporting sub-elements were used for a quantitative evaluation and ranking order.

Two similar sets of evaluation criteria were established for the Severance and Canopy Removal concept candidates so that quantitative evaluation and ranking order could be attained.

Tables I and II provide results of the Initiation System design concept evaluation.

Tables III and IV provide results of the Severance and Canopy clearance design concept evaluation.



6.2 Rationale for Evaluation Criteria

Rationale and grading technique for Tables I and III is given in the following paragraphs:

In the evaluation process a maximum value was assigned when the supporting element imposed no adverse effect. A minimum rating was applied when the element contributed an unacceptable condition.

6.2.1 Safety

When dealing with ordnance devices and specifically with canopy severance systems the hazard of transparency fragments is always present. The effects of the fragments are related to the type of material and the fragment size (which can be controlled to some extent by the fracturing system (installation)). The ground emergency supporting element refers to speed and efficiency whereby cockpit ingress and egress can be achieved. Detonation effects is defined as the potential injury a crewman may experience from the detonation noise and debris.



6.2.1 Safety (Continued)

The reliability element of safety places emphasis on system complexity and maintainability. In the absence of a detailed reliability and failure mode analysis "complexity" can be graded by the number of component parts involved in a concept. Maintainability refers to the estimated repair and replacement time for the components.

6.2.2 Performance

Overhead fracturing systems and some perimeter cord installations reduce and interfere with vision. The size and location of the concept components may reduce cockpit clearance and adversely affect the crewman's performance.

Sequencing compatibility with the primary system is essential in assuring successful system performance and the preclusion of injury. For example, early canopy severance will subject crew member to buffetting. Time delay during any egress must be kept to the practical minimum to reduce injury potential.



SPACE ORDNANCE SYSTEMS

6.2.3 Development Risks

In this area we deal with advanced technology and test requirements. New and advanced technology refers to the advances in the state of the art which are required to develop an advanced idea concept. Test requirement is the assessment of the amount of testing required to qualify the components and the complete system.

6.2.4 Installation Effects

The installation effects element involves the consideration of the weight increase due to concept installation, and the cockpit volume required to install the concept components. In addition the airframe modification and aircraft systems modifications must also be considered.

6.2.5 Injury Potential

Injury potential is the potential for the concept to cause injury during inadvertent or planned actuation. This includes injury to aircrew and ground crew during ground egress. This also includes the inherent and anticipated hazards presently associated with each design concept.



TABLE I
INITIATION SYSTEMS CONCEPT EVALUATION

EVALUATION CRITERIA	CRITERIA TOTALS						
	POINTS	1	2	3	4	5	6
SAFETY							
- Ground Emergency	10	8	9	10	10	10	10
- Detonation Effects	8	5	4	8	8	2	3
- Reliability/Maintainability	12	7	8	11	12	9	10
- System Complexity	5	1	3	5	4	2	3
PERFORMANCE							
- Function After Bird Strike	20	9	10	18	20	14	15
- Sequencing Compatibility	15	13	10	15	15	12	12
- Time Delay	5	4	3	4	5	2	2
DEVELOPMENT RISKS							
- Advanced Technology	10	4	4	9	10	8	7
- Test Requirements	5	1	2	4	5	3	3
INSTALLATION EFFECTS							
- Airframe Modification	10	2	3	9	8	6	4
- Systems Modification	8	5	6	7	7	2	3
- Weight Added to Canopy	5	5	1	2	3	4	4
TOTALS	113	64	63	102	97	74	76

SPACE ORDNANCE SYSTEMS

**TABLE II
INITIATION SYSTEMS CONCEPT EVALUATION**

CRITERIA	POSSIBLE TOTAL POINTS	CONCEPT NUMBER					
		1	2	3	4	5	6
Compatibility with T-38 Airframe and Systems	10	2	3	10	9	4	3
Added Injury Potential	10	4	4	10	10	8	8
Ground Crew Injury Potential	10	4	4	10	10	7	7
Maintenance	10	2	3	10	9	4	5
Reliability	10	5	6	10	9	7	8
Initial Cost	10	5	6	9	8	7	10
TOTAL POINTS	60	22	26	59	55	37	41



TABLE III
SEVERANCE AND CANOPY REMOVAL CONCEPT EVALUATION

EVALUATION CRITERIA	CRITERIA TOTALS		CONCEPT NUMBER					
	POINTS		A	B	C	D	E	F
SAFETY								
- Fragment Hazard	13		4	9	9	5	15	10
- Ground Emergency	10		6	7	2	8	10	9
- Detonation Effects Noise	7		4	3	3	5	7	7
- Reliability/Maintainability	15		1	13	12	2	14	15
- System Complexity	5		2	3	1	3	4	5
PERFORMANCE								
- Function after bird strike	20		3	10	9	2	19	20
- Vision	15		4	10	9	6	15	15
- Clearance	5		5	6	3	5	9	10
DEVELOPMENT RISKS								
- Advanced Technology	10		5	8	9	5	10	7
- Test Requirements	5		2	3	2	1	5	4
INSTALLATION EFFECTS								
- Weight	10		7	6	5	8	9	10
- Volume	5		3	2	1	4	4	5
TOTALS	125		46	80	65	54	121	117

TABLE IV
SEVERANCE AND CANOPY REMOVAL CONCEPT EVALUATION

	CONCEPT						
	POINTS	A	B	C	D	E	F
<u>AIRCREW INJURY POTENTIAL</u>							
LOSS OF LIMBS	10	2	9	8	2	10	10
LOSS OF SIGHT	10	3	8	8	2	10	10
PERMANENT HEARING IMPAIRMENT	10	7	6	6	8	9	10
LACERATIONS	10	3	7	6	4	10	9
BURNS	10	4	7	1	5	10	9
<u>T-38 SYSTEM DEGRADATION</u>							
SEQUENCING OF SYSTEM	10	7	7	5	6	10	10
SEAT TRAJECTORY	10	9	6	10	8	7	7
<u>SCREENING CRITERIA - CPE CONCEPTS</u>							
COMPATIBILITY WITH T-38 AIRFRAME AND SYSTEMS	10	7	8	5	6	9	10
FUNCTION AFTER BIRDSTRIKE	10	5	8	7	6	9	10
GROUND CREW INJURY POTENTIAL	10	7	8	6	5	10	9
INITIAL COST	10	10	8	2	9	6	7
TOTAL	120	64	82	64	61	100	101

6.3 Concept Evaluation Results

6.3.1 Initiation Systems

Results from Tables I and II were added together to determine final quantitative results. Table V provides the final evaluation points total summary.

TABLE V
INITIATION SYSTEMS CONCEPT EVALUATION SUMMARY

	<u>1</u>	<u>2</u>	<u>3</u>	<u>4</u>	<u>5</u>	<u>6</u>
TABLE I	64	63	102	97	74	76
TABLE II	22	26	59	55	37	41
TOTALS	86	89	161	152	111	117

Concept Number 3 received the highest points score and therefore should be considered the primary initiation system. Concept Number 4 scored the second highest points score and therefore should be considered as the alternate initiation system. Therefore SOS recommends that detail design should be completed for concepts 3 and 4.



SPACE ORDNANCE SYSTEMS

6.3.2 Severance and Canopy Removal

Results of Table III and IV were added together to determine final results. Table VI provides the final evaluation points total summary.

TABLE VI
SEVERANCE AND CANOPY REMOVAL CONCEPT EVALUATION SUMMARY

	<u>A</u>	<u>B</u>	<u>C</u>	<u>D</u>	<u>E</u>	<u>F</u>
TABLE III	46	80	65	54	121	117
TABLE IV	64	82	64	61	100	101
TOTALS	110	162	129	115	221	218

Concept E received the highest point total and therefore should be considered the primary severance and canopy removal concept. Concept F received the second highest point total and should be considered the alternate severance and canopy removal concept.

Therefore, SOS recommends that detail design should be completed for concepts E and F.



GLOSSARY

- Ancillary Hardware - Subordinate, subsidiary hardware.
- Ballistic - The flight characteristics of a projectile.
- Biodynamic - Of or relating to physical force or energy.
- Bisector - A straight line that bisects an angle or a line segment.
- Buffeting - To drive, force, or move by or as if by repeated blows.
- Cable Yoke - Airframe attachment with cable adjusters for each cable initiator.
- Convergent Plane - Plane parallel to the cord axis.
- Droque Chute - A small parachute for stabilizing or decelerating.
- Egress - A place or means of going out.
- Ejection - A thrusting out ward by force of an explosive charge.
- Emanating - Coming out from a source.
- Hybrid - A composite of two different materials.
- Laminated - Used to denote that a product consist of different layers of material bonded together.



GLOSSARY (continued)

- Lanyard - Cable used to activate primary jettison system.
- Longitudinally - Running the length or the lengthwise dimension of the canopy.
- Monolithic - One ply of "as cast" sheet, plastic, or glass.
- Polycarbonate - A family of polymers of which only the "bisphenol A" type is considered for structural aircraft glazing.
- Pyrotechnic Material- A combustible substance used for ignition.
- Radially - Developing uniformly around a central axis.
- Rarefaction - A region of minimum pressure in a medium traversed by compressional waves.
- Spalling - Small particles flaking off of a glass or plastic sheet. Spall from the inside surface of a windshield as a result of high velocity impact could be harmful to the pilot.
- Stretched Acrylic - Stretching a heated plastic sheet either in two perpendicular directions (biaxial) or in all directions (multiaxial) in the plane of the sheet to improve the physical properties by reorienting the molecules.
- Transparency - The property of a material by which a negligible portion of the transmitted flux



GLOSSARY (continued)

undergoes scattering. Also any optically clear structure.

Witness Plate

- Object or material placed behind windshield to test for spalling.



SPACE ORDNANCE SYSTEMS

ACRONYMS

- CPE - Clear Path Egress
- FLSC - Flexible Linear Shaped Charge
- MAGNA - Materially And Geometrically Nonlinear Analysis
- MDAC - McDonnell Aircraft Company
- MDC - McDonnell Company
- MDF - Mild Detonating Fuse
- SMDC - Shielded Mild Detonating Cord
- SOS - Space Ordnance Systems
- TTC - Thru-The-Canopy
- WPAFB - Wright-Patterson Air Force Base

