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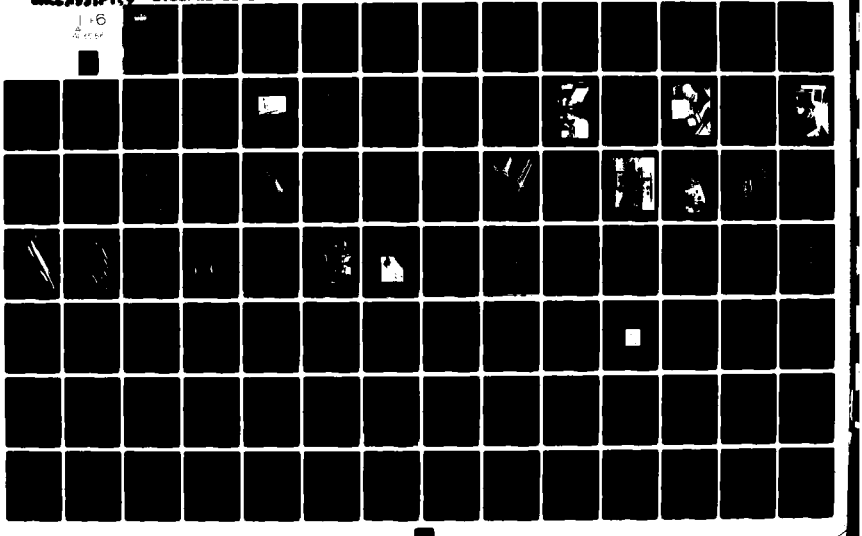

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FIELD OF INTEREST: 19.03

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PROCEEDINGS

A WORKSHOP IN SURVIVABILITY AND COMPUTER-AIDED DESIGN

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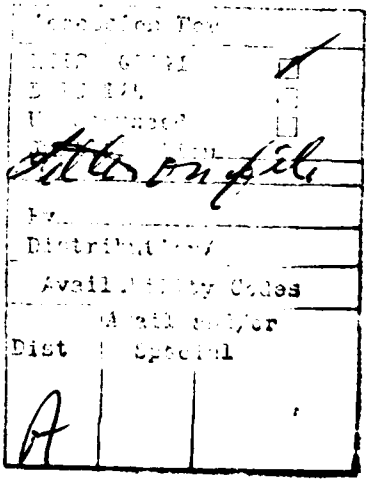

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JTCG/AS COMPUTER-AIDED DESIGN WORKSHOP
DISCUSSION TOPICS

At the conclusion of the computer-aided design workshop held in Ft. Worth, Texas from April 6-9, 1981, a roundtable discussion was held. Both Government and industry representatives participated, including:

Bob Ball, Naval Postgraduate School, Monterey, CA
Ken Bailey, Systems Survivability Branch, Naval Weapons Center, China Lake, CA
Richard Ricci, Automation Development Organization, Lockheed, CA
Joel Lindsey, Defense Design, Lockheed, GA
Tim Horton, JTCG/AS Center Office
Alvars Ozolins, Ballistics Research Laboratory, Aberdeen, MD
David Berry, Naval Air Systems Command
John Hartung, Grumman Aerospace
Bob Ritter, Aero Engineering Division, Naval Air Development Center, Warminster, PA
Al Vachris, RAIS Project Leader, Grumman Aerospace
John Aldridge, JTCG/AS Central Office
Tom Weir, Northrop Aircraft, CA
Larry Kelly, Flight Dynamics Laboratory Structural Division, WPAFB
Don Tuttle, Lockheed, CA
Darrell Liardon, Operation Analysis Group, Bell Helicopter
Dan Pierce, Grumman Aerospace
Millard Mitchell, Systems Analysis Division, Naval Air Development Center, Warminster, PA
Joe Arrighi, Fairchild-Republic
Pat Donnelly, Boeing Vertol
Jerry Wallick, AF Aeronautical Systems Division, Systems Engineering, WPAFB
Gordon Launders, Vought Corp.
Paul Chan, Vought Corp.
Ray Moonon, Rockwell/North American Aircraft Division
Gary Jackson, Lockheed, GA
David Watson, Armament Systems, Inc.
Pat Coffield, AFATL/DLYD, Eglin AFB
Earl Weaver, Vulnerability Analysis Division, Ballistics Research Laboratory, Aberdeen, MD
Clarence Winterrowd, General Dynamics, Ft. Worth, TX

The following pages are a summary of the roundtable discussion, as categorized by the seven discussion topics.

1. Near-term interaction/integration of SV with CAD/ICAD

The workshop participants agreed there is a definite near-term need for interaction and integration of survivability (SV) data with computer-aided design (CAD) and integrated CAD (ICAD) programs. A major JTCG/AS objective is to promote survivability as a design discipline and its integration into the design process. The most effective means for doing this should be to promote a successful integration of SV with CAD processes. It was felt, however, that the survivability community needed to draw the CAD community to it, not the other way around. The Design Criteria and Industry Interface (DCII) subgroup may provide the mechanism for doing this.

The survivability community, however, needs to be better informed about CAD/ICAD; be trained, understand it, and be able to use it. Conversely, designers employing CAD/ICAD need a greater knowledge of SV before survivability can become an integral part of CAD/ICAD design efforts. The ideal time for this integration to occur seems to be during the conceptual design phase. Basic survivability requirements are established during the concept phase based on preliminary cost benefit analyses. Frequently, this must be done on a very short term basis and the eventual achieved SV in the delivered system will depend largely on how well this is done There is no effective way to assess the value of various combinations of SV design features in so short a time, without the aid of CAD. Since there are plans to include SV modules in most CAD/ICAD programs that are on-line or are under development, the CAD/ICAD community will need a means to convert from conceptual geometry models to analytical models. Present survivability models, such as FASTGEN, are advanced design analysis tools and do not lend themselves to the conceptual design phase.

2. What can JTCG/AS provide industry to facilitate/ expedite integration?

CAD Methodology

Industry needs the assistance of DOD in defining and developing CAD methods that are compatible with SV assessment techniques. Whether the method is for conceptual studies, preliminary design or full scale development it must permit determining SV design features, evaluating their effectiveness, and determining their costs in terms of weight, dollars and performance. Considering SV in the design of each piece or part will allow adding the sum of the parts to obtain a complete SV assessment.

It is at the conceptual design phase, not preliminary design, that SV modules could provide an initial SV assessment that may prevent costly design changes later. The trend is to design first for performance and consider SV an add-on. The reality is that SV is part of performance.

SV Design Requirements

The current trend is to include SV in new requirements documents so that it will be designed into the aircraft and not added on at a later date. The A-10 is an example of SV being included from the beginning.

The F-18 and the V/STOL were cited as examples of survivability add-ons. The consensus was that the CAD/ICAD community needs to be educated on the importance of SV, and the emphasis should come from DOD as well as the JTCG/AS. If this is done, then computer-aided design and SV can be integrated sooner.

Historically, however, there haven't been definite SV requirements in the early stages of conceptual design. Conceptual designers cooperated with operational analysts and system analysts, and although survivability was inherent in some designs, it only occasionally seemed to be significant enough to affect the total design. (Exceptions are the A-10, H-60 and H-64.) An airplane was evaluated on such factors as performance, weight, and fuel consumption but not on its SV criteria.

The specifications and standards sponsored by the JTCG/AS Central Office require SV in all acquisitions or major MOD programs. These requirements show up in RFPs as well as RFIs and detail specifications. The problems that arise in complying with the requirements fall into two categories: 1) convincing industry that the Services are serious about survivability and 2) integrating the classified specification requirements into the guidance provided to designers.

In convincing industry that Government is serious about SV, it was suggested that documentation be more specific. If SV is not required through the specification, no one will pay attention to it. If the requirements are too specific, however, they may limit the designer and possibly cause excessive cost and weight penalties. Industry would be more responsive, especially to RFPs, if financial incentives were added. If RFPs/RFIs include extra rating points for increased survivability or

if flyoff competitions were held more regularly, such as in UTTAS, it would ensure that SV and CAD are included in the overall design.

Becoming familiar with survivability often involves a better understanding of the threat and threat scenarios, since aircraft design is driven by the threat scenario. Consequently, integrating SV with CAD will be somewhat influenced by availability of classified data. This is especially true for requirements for radar cross section. If the need-to-know is well established, however, the data is obtainable in classified reports, especially those distributed by JTCG/AS. It is the responsibility of the Government to ensure that documents referenced in RFPs/ RFIs or in specifications are made available to industry. Where limited distribution documents are involved (U.S. Government only-T&E etc.), it is very helpful if the procuring agency provides a bidders' package containing all the required documents, computer programs, or methodology.

The problem of communicating SV requirements should be alleviated soon. MIL-STD-2069, Requirements for Aircraft NonNuclear Survivability Program, is now available. It is a general specification for use in conjunction with the aircraft detail specification in tailoring SV requirements for each specific aircraft. Aircraft detail specifications, such as the Army's MIL-STD-490 style Prime Item Development Specifications, the Navy's soon to be published SD24L, and the Air Force's forthcoming MIL-PRIME Specs, all address SV requirements in unequivocal detail. Particularly important though is that MIL-STD-2069, on which the aircraft detail specification is based, is only written after a careful conceptual phase has examined the costs and benefits of various levels of survivability design, and "sold" the program to Service Chiefs and Congress.

Conceptual CAD-Government/Industry Interface To Establish and "Sell" SV Design

CAD, with SV analysis and cost benefit capability, will make it possible to examine various levels of SV design of single aircraft, and various combinations of proposed aircraft of varying configurations. It will help determine the best way to perform the service mission, optimized by any combinations of specified parameters (e.g., performance, size, weight, cost, mix of aircraft, etc.). It will permit doing this fairly accurately, within the often extreme time limitations imposed by the needs of Service Headquarters, Service Secretaries, OSD and Congress. The political and economic reality of the

80's will be that only those programs with credible designs and credible cost predictions will be funded. For SV features to be included in any new or service life extension design, CAD must be able to show the costs in terms of weight and dollars and the benefit of each SV design requirement.

3. Definition of a "common data base"

Government and industry should define a common data base, which will be very difficult because they are separate, isolated groups. Since a three-dimensional data base seems to be necessary, this may be accomplished by defining vulnerable areas, by using the geometry of basic components, and through using $P_{k/h}$. Another viable data source would be a library on $P_{k/h}$, scenarios, threats, components, engines, etc. This could help establish a whole network of capabilities that could blend to define the configuration of such items as components and systems. Communicating the configuration without interpretation is necessary, which would mean topology.

Once SV is entered in the conceptual design phase, then the survivability community could establish a simple model to use in that phase. In this manner, a simple library could be built, and the vulnerability specialist could move the components around the airplane and do the analysis. The model could be a simplified tool for conceptual design and cost analysis, and could provide inputs to other more sophisticated programs as a long-term goal as well.

The JTCG/AS bibliography could also be used in setting up a common data base. By reformatting the indexing system with the subject codes, users could search for data items by subject and not merely through the report documentation titles.

4. Who else needs to be involved?

The aircraft designer needs the survivability engineer to tell him how to arrange the components in the airplane for improved survivability, whether it be from ground fire, IR missiles, etc. A SV engineer needs a simple model to assess the design that the configurators come up with. The computer graphics system will help refine that model or tool so as to differentiate between separation and redundancy. Thus, the SV engineers can put in any SV features overlooked by the airplane designer.

Because propulsion engineers have a large investment in CAD, they should be included in future workshops and meetings.

5. How well defined is the CAD community?

The computer-aided design community is fairly well defined. AIAA has a new CAD/ICAD subgroup. There are CAD organizations from the university to corporate level. The IEEE addresses the CAD community through its user's group. The aircraft designers, however, are integrated with the automotive designers.

6. Coordination/standardization/development objectives

Coordination

JTCG/AS hopes to publish a security guide addressing basic SV data. As an interim guide, the Navy Survivability Classification Guide is available through the JTCG/AS Central Office. Essentially, the design requirements and the effects of munitions against airframes will not be classified higher than Confidential.

Better coordinated documentation will help the liaison at the working levels with the JTCG's. This is true in vulnerable areas, especially in vulnerability assessment techniques.

Standardization and Development

Better coordination will hopefully lead to a standardization of susceptibility models, which is needed. The models should be simple, if possible, and geared first for use with radar cross sections, IR, countermeasures, and camouflage.

Because CAD can be of help with its inherent capability to change ideas quickly, JTCG/AS should look at developing more simplistic tools. These tools can be used in the conceptual design phase. For example, with a library of $P_{k/h}$'s at CDIC for use in the conceptual and preliminary design phases, a designer can do an assessment and redo it quickly if it's found to be inaccessible or unsuitable. In this manner, the designer can accomplish rapid, progressive survivability assessments as they work through the conceptual design. The question remains, however, of who should actually develop the tools and the formats.

7. Future workshops

Yes, future CAD workshops would be beneficial, although separate workshops for special interest groups also might be feasible. The next session should address threat, the CAD/ICAD/CAM ability to address threat, and the types of damage caused by the threat. The designers should integrate these areas with any analysis that is done in order to evaluate the capabilities of the aircraft. JTCG/AS could then publish the collective results of the analysis.

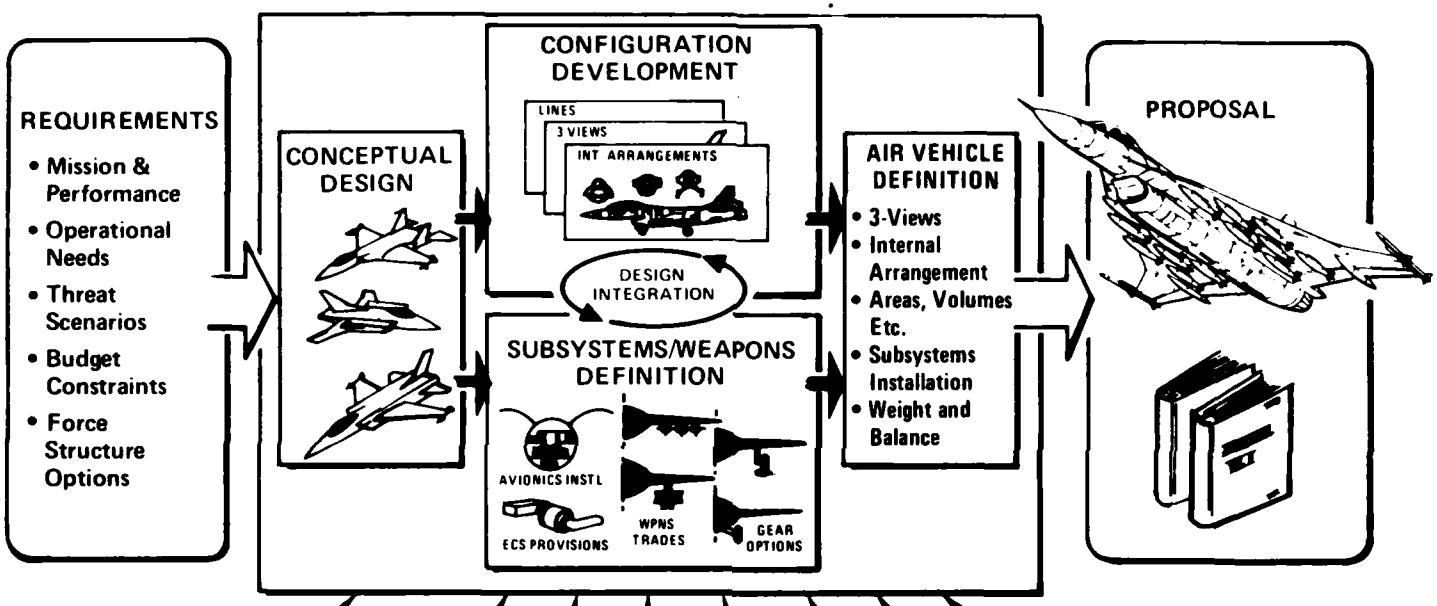
If a workshop is held again in a year, possible locations could be Wright-Patterson AFB, OH where the CDIC is located or the Naval Weapons Center in California.

THE ADVANCED DESIGN PROCESS

Robert W. Lynch
General Dynamics
Ft. Worth, Texas

THE ADVANCED DESIGN PROCESS

BASIC PROCESS:



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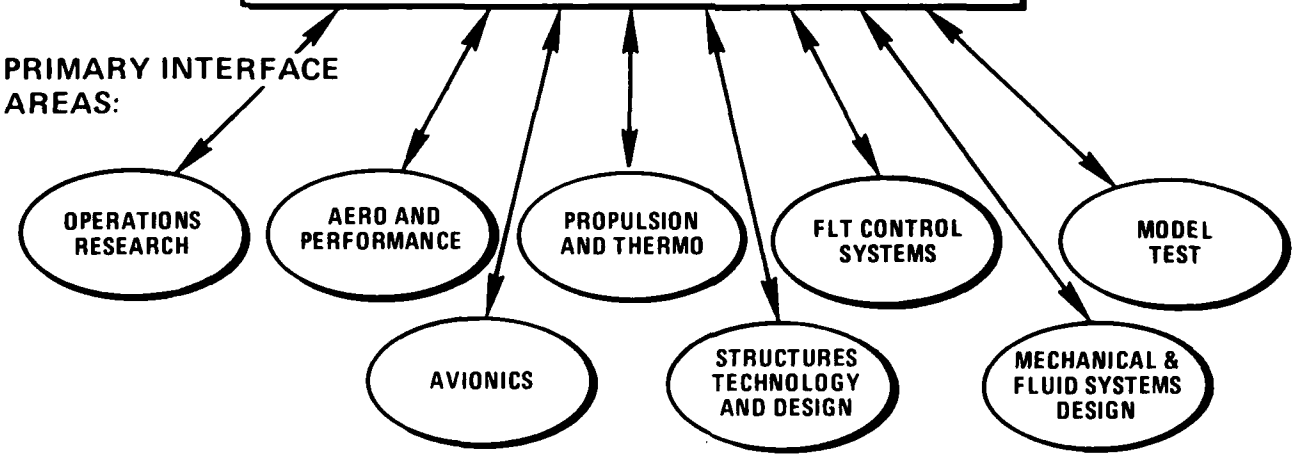

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ADVANCED DESIGN PROBLEM

- HAND METHODS CAN'T KEEP PACE WITH WORK VOLUME
  - THREE VIEWS
  - INBOARD PROFILES
  - CONFIGURATION LAYOUTS
  - WIND TUNNEL MODEL LINES
  - VOLUME MEASUREMENT
  - AREA CURVES
  - PERSPECTIVE DRAWINGS
  - CLEARANCE STUDIES
  - LANDING GEAR MOTIONS
  - PILOT & SENSOR OBSCURATION DIAGRAMS
  - WEIGHT AND BALANCE
- CONTINUAL "SHORT FUSE" OPERATIONS REQUIRE "QUICK RESPONSE" CAPABILITY

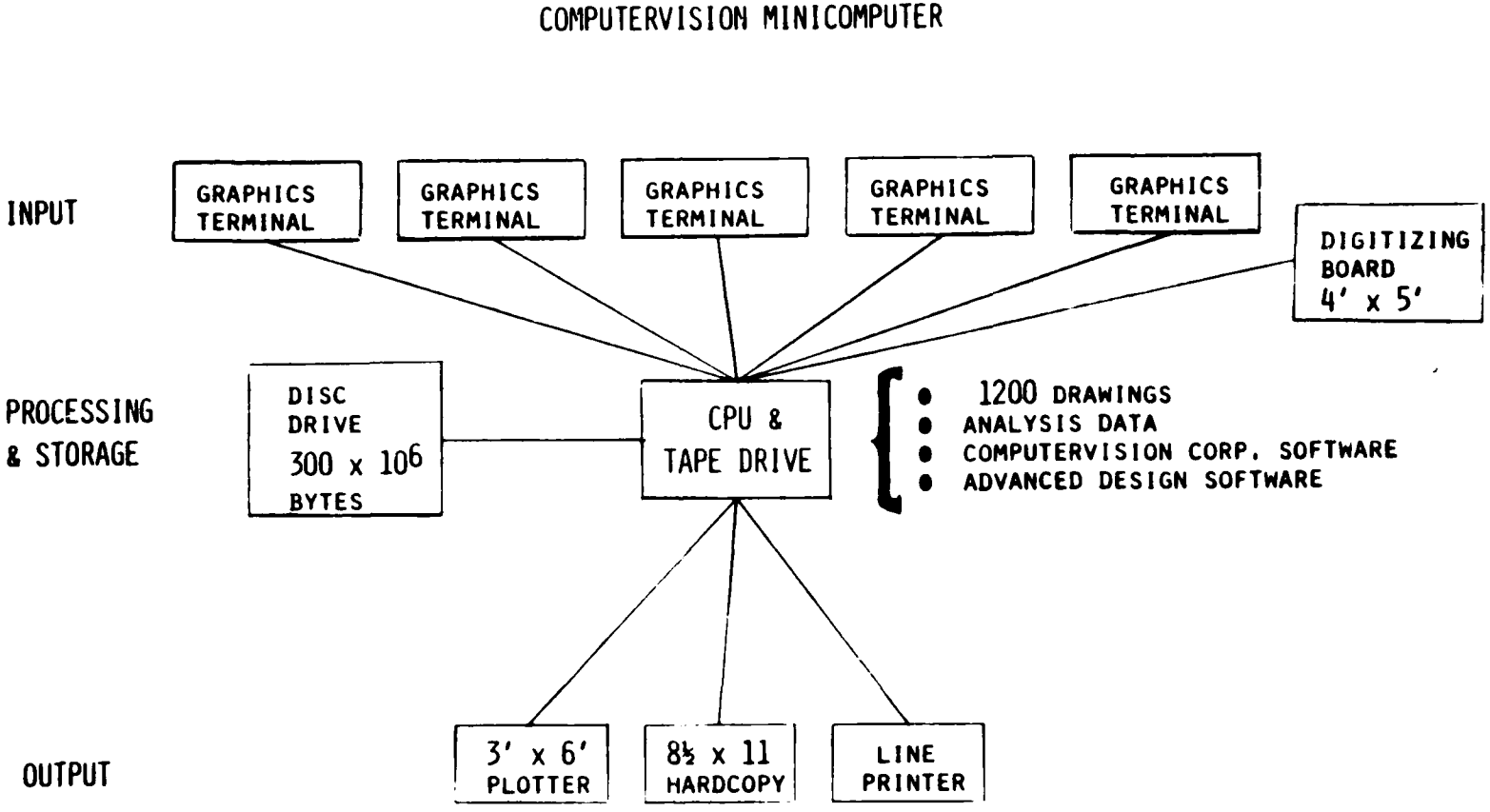
OBJECTIVES

- INCREASE PRODUCTIVITY
  - DECREASE TIME SPENT
  - INCREASE TECHNICAL QUALITY
  - IMPROVE DRAWING QUALITY AND CONSISTENCY
  - INCREASE PROPOSAL QUALITY
  - DECREASE TEDIOUS REPETITIVE WORK
  - DECREASE COST OF FINISHED ART WORK
  - IMPROVE DEPARTMENTAL DATA EXCHANGE

BY

DEVELOPING A COMPUTER GRAPHICS SYSTEM
FOR USE IN ADVANCED DESIGN

SYSTEMS ARCHITECTURE



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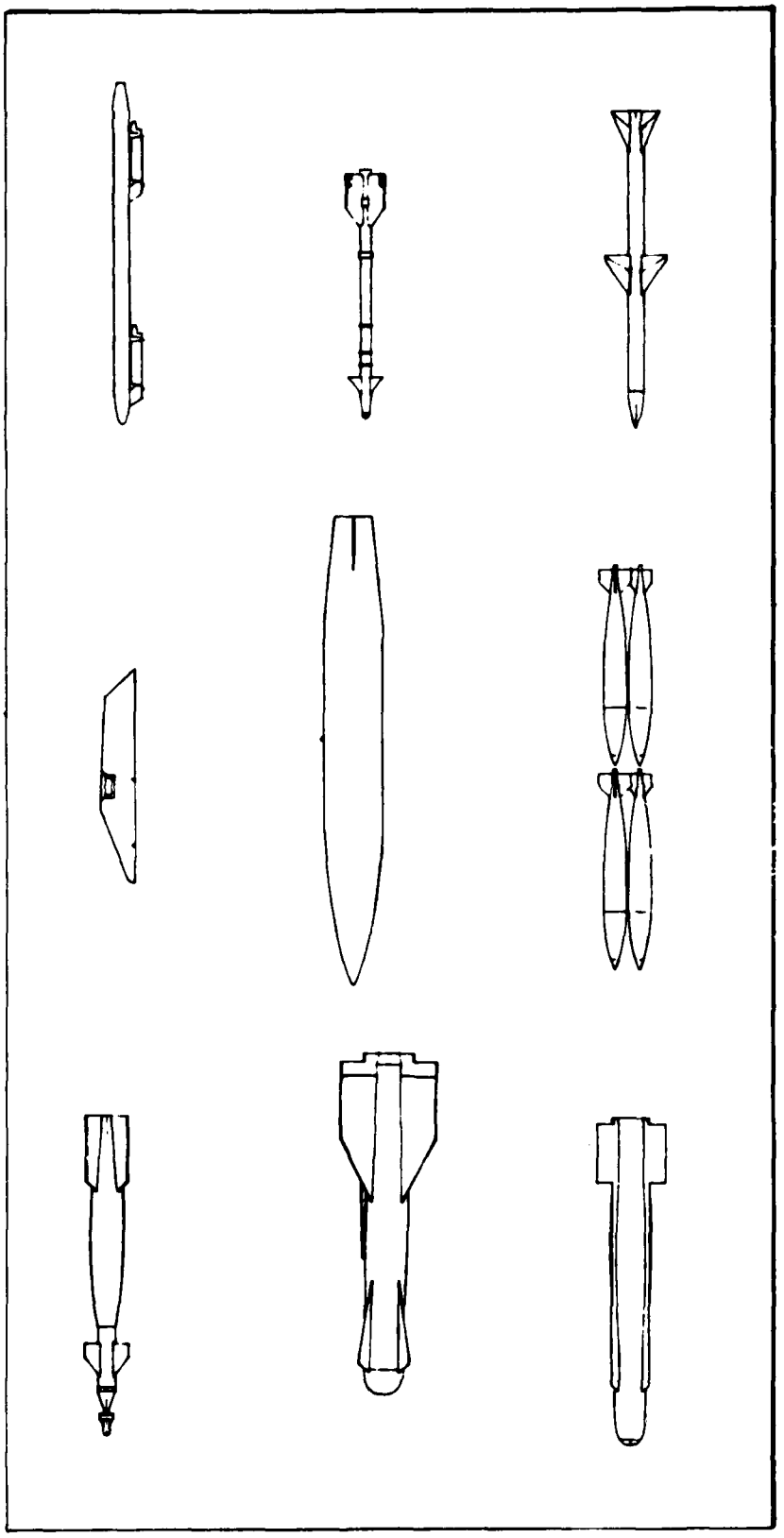
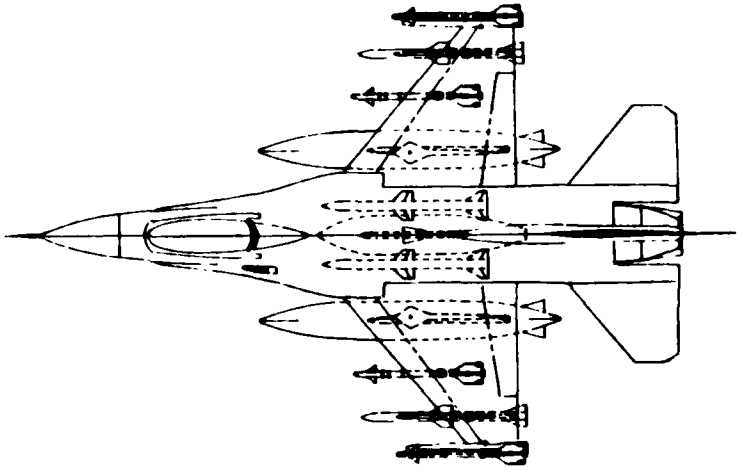
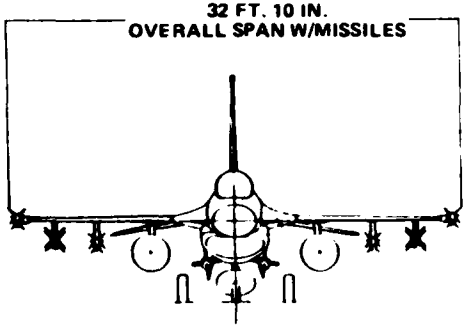
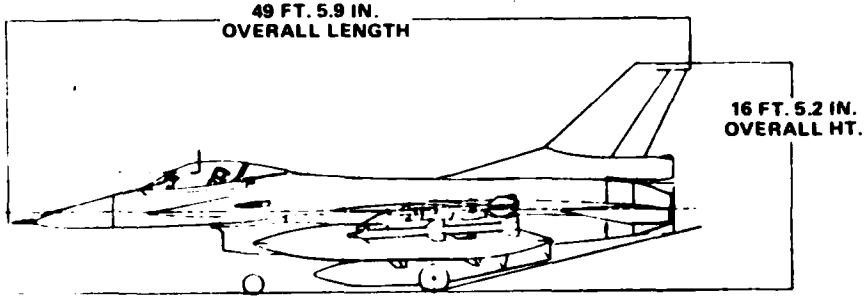


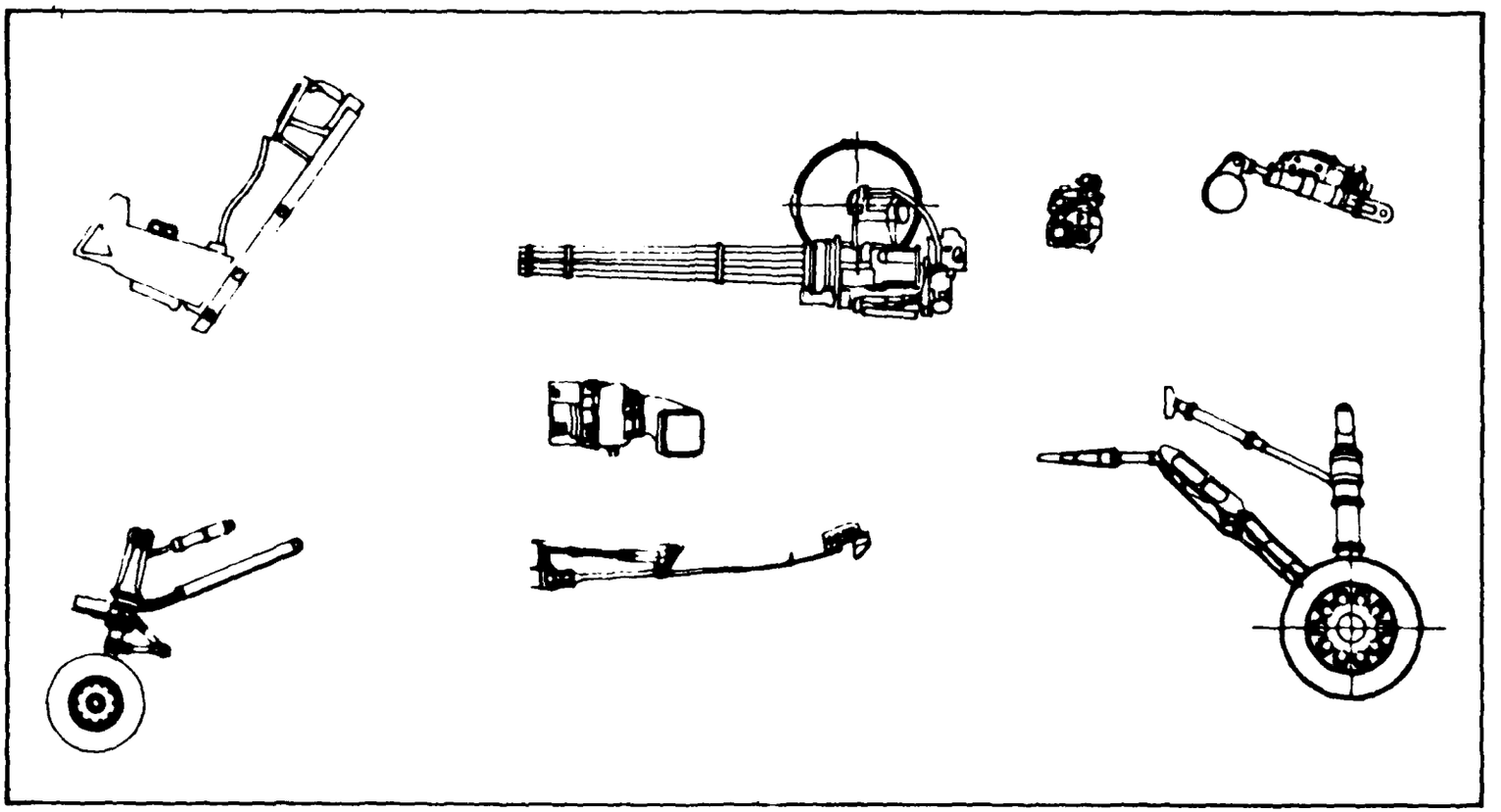
F-16 THREE VIEWS



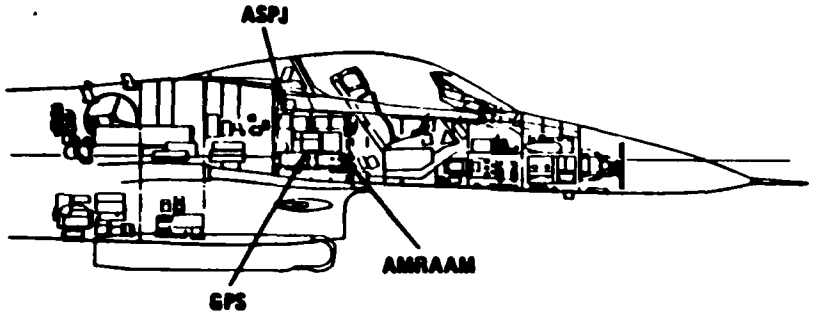


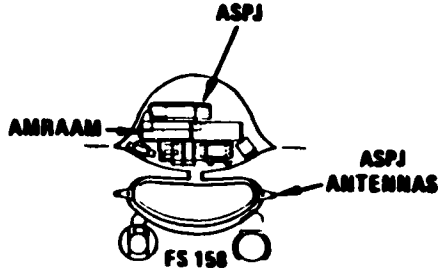


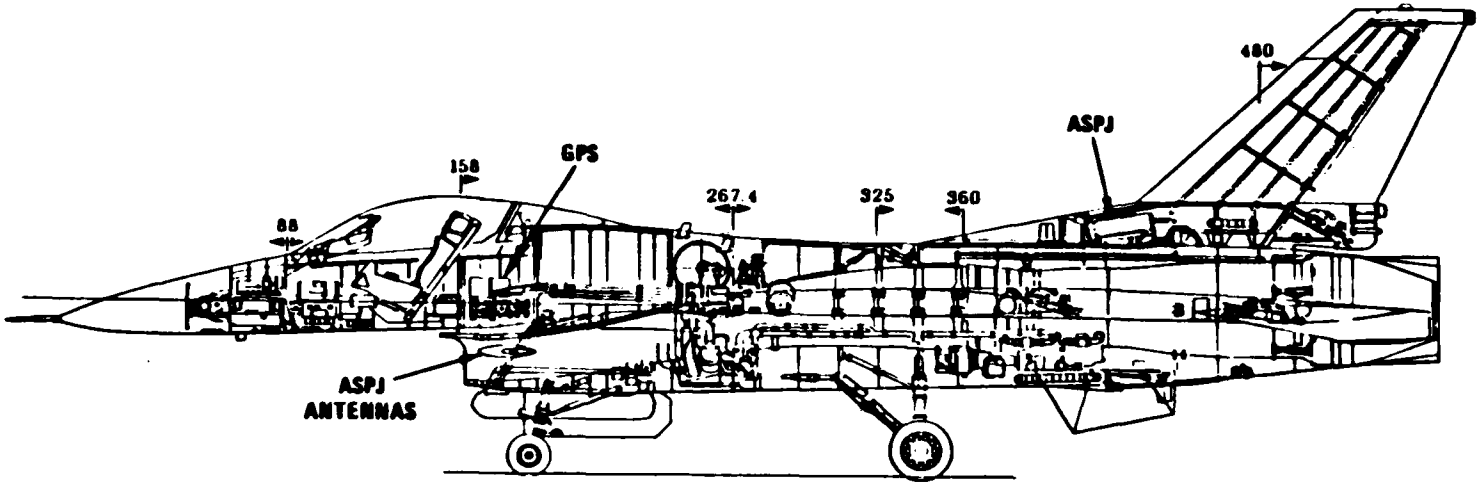
PARTS LIBRARY ESTABLISHED



EXAMPLES OF INTERNAL ARRANGEMENT

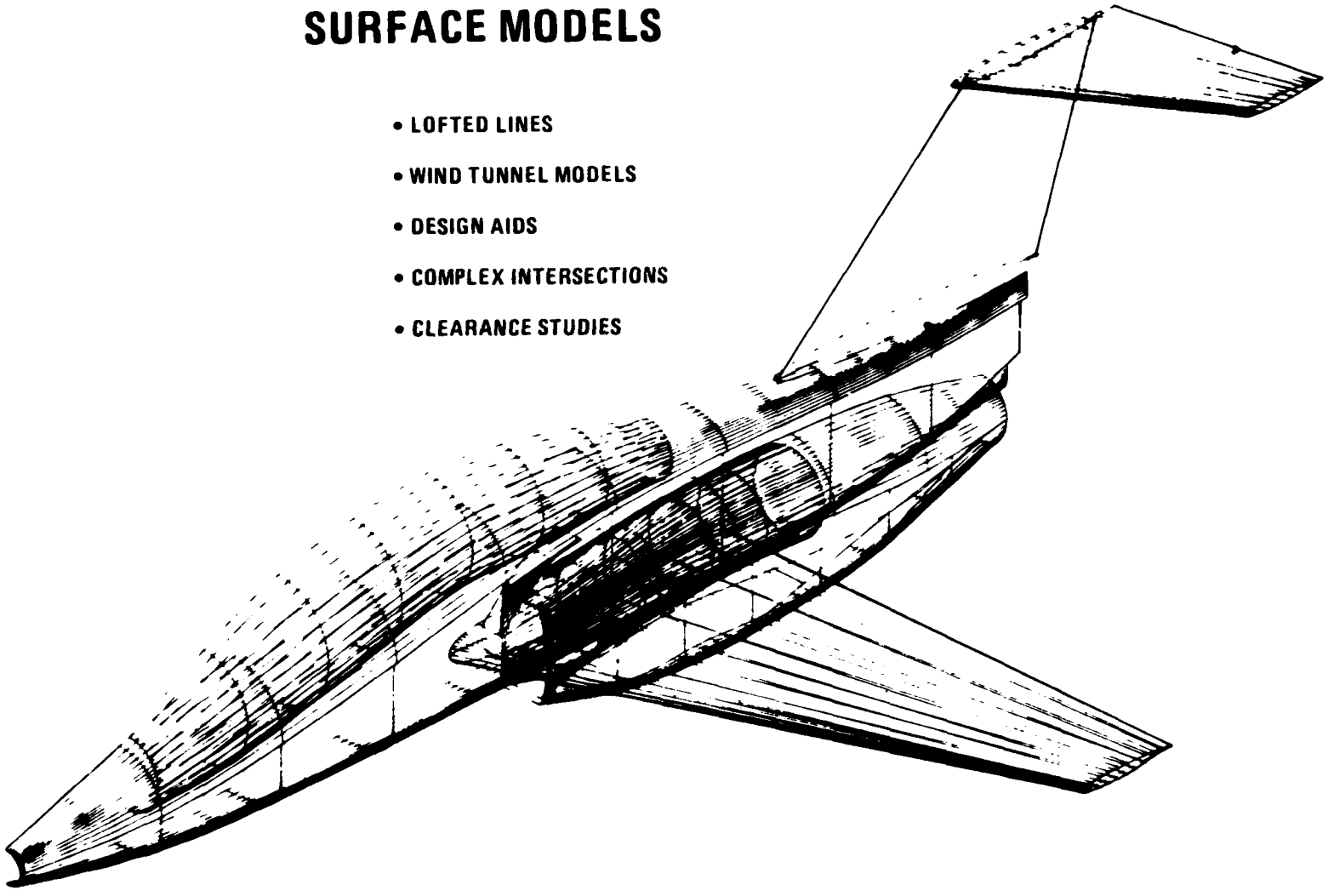




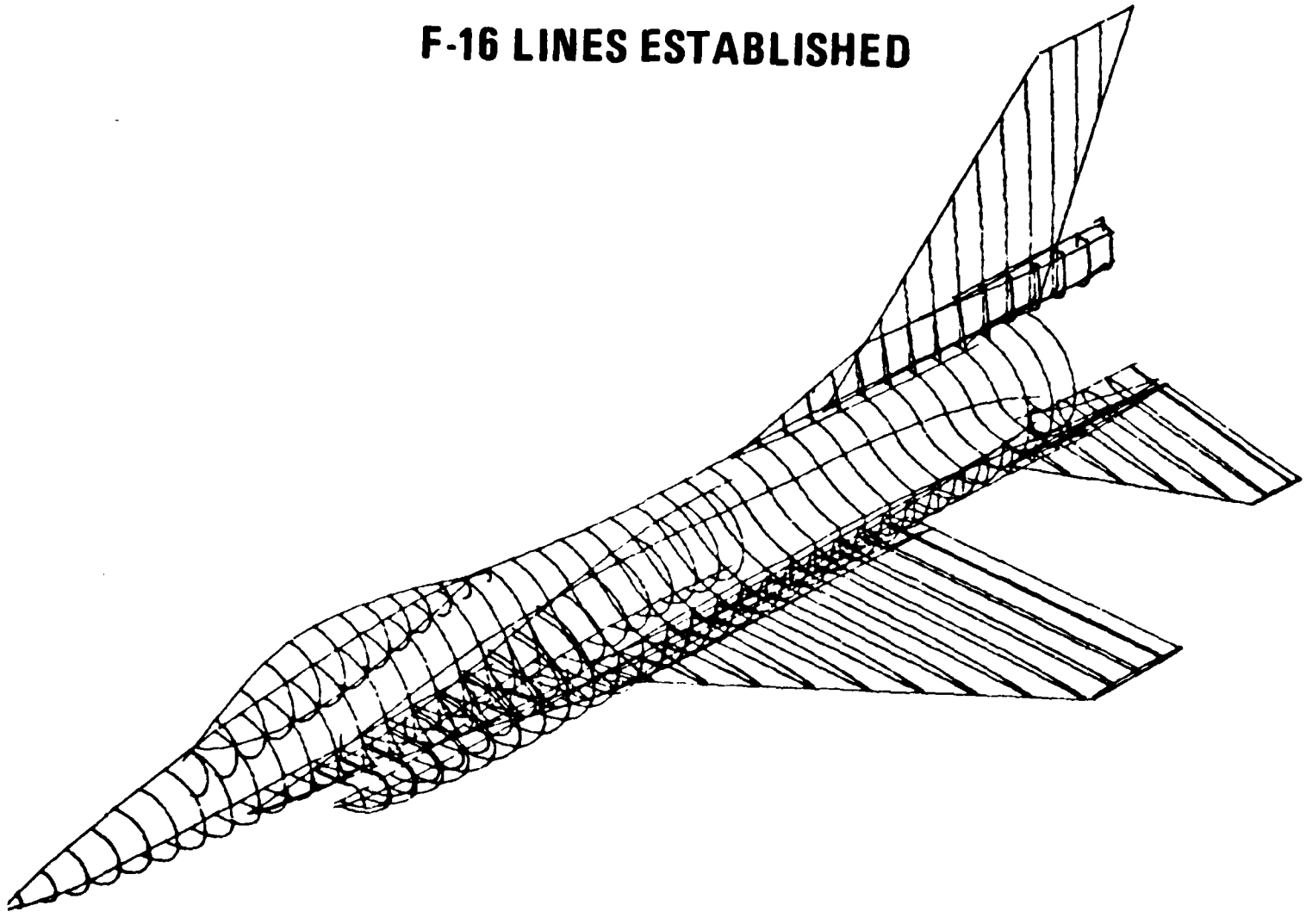


SURFACE MODELS

- LOFTED LINES
- WIND TUNNEL MODELS
- DESIGN AIDS
- COMPLEX INTERSECTIONS
- CLEARANCE STUDIES



F-16 LINES ESTABLISHED



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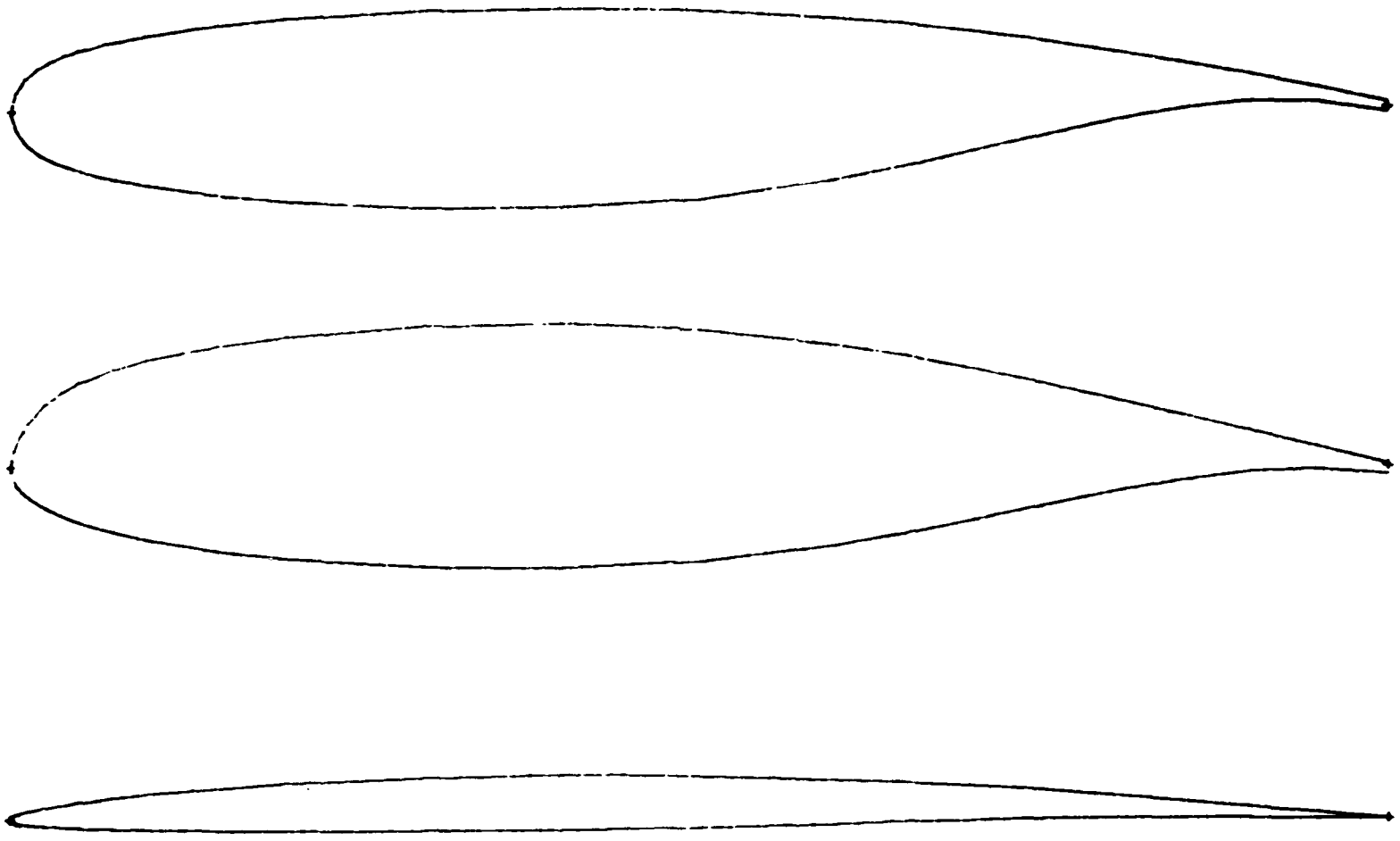
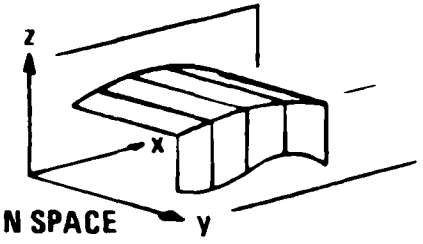
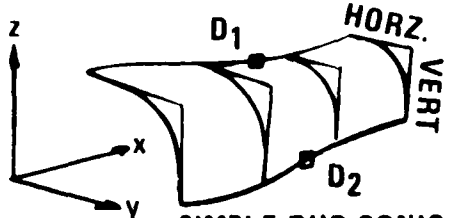


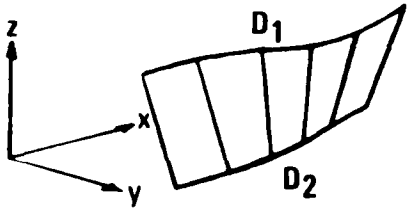
FORT WORTH USES PLOYCONIC SURFACES



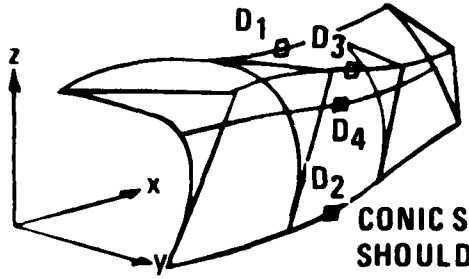
LINE IN SPACE



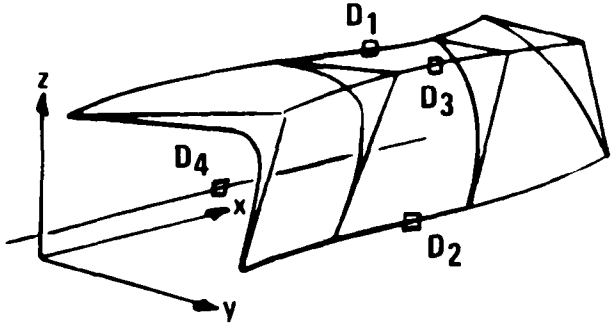
SIMPLE RHO CONIC SURFACE



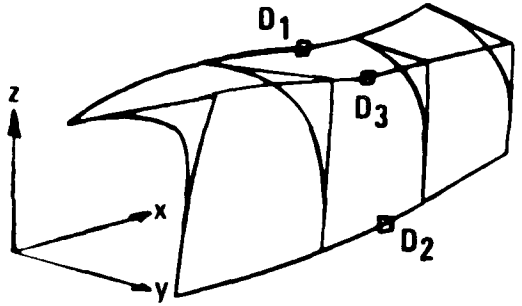
WARPED PLANE



CONIC SURFACE WITH
SHOULDER LINE &
VARIABLE EDGE SLOPE

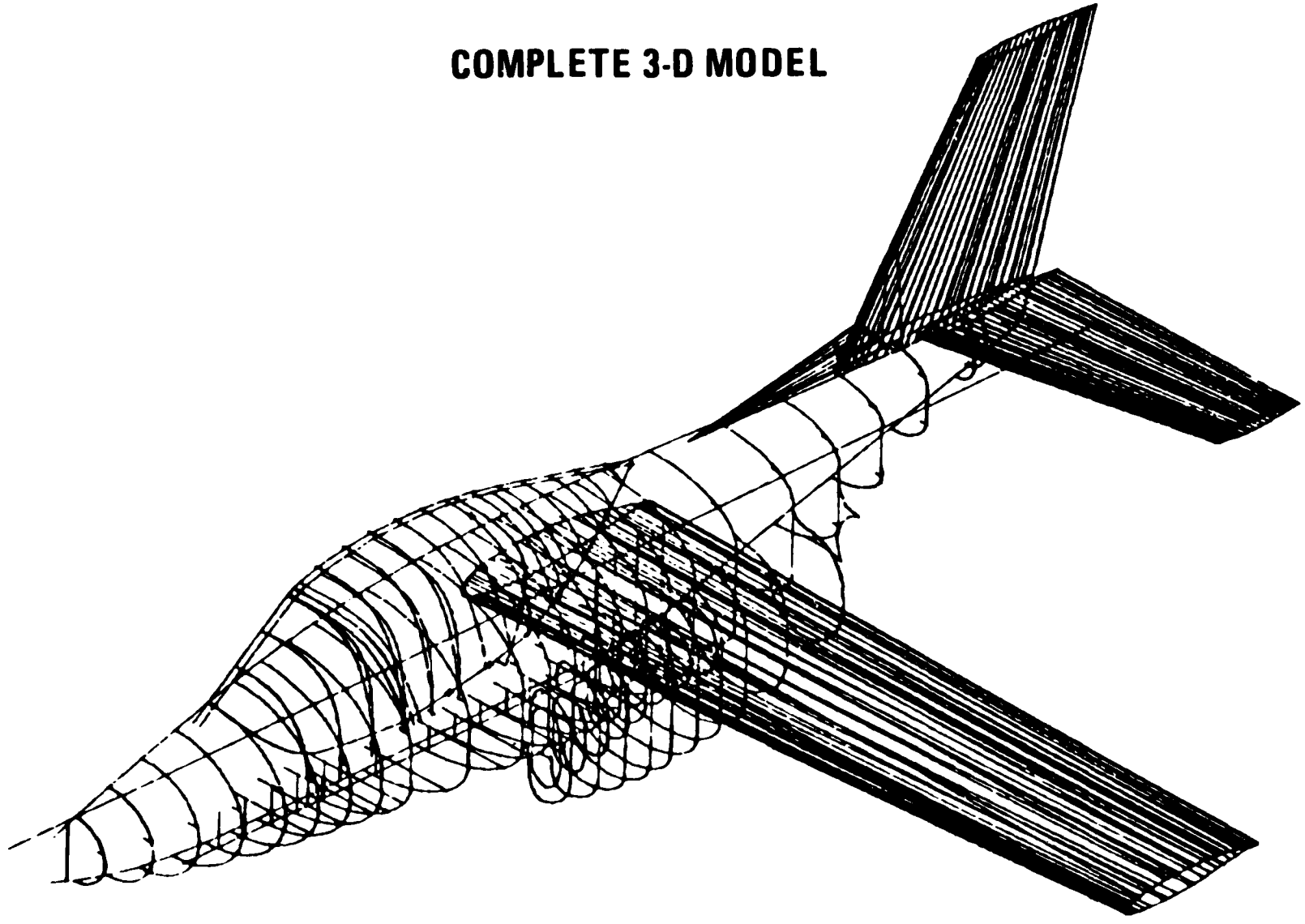


CONIC SURFACE WITH
VARIABLE RHO LINE
AND EDGE SLOPES

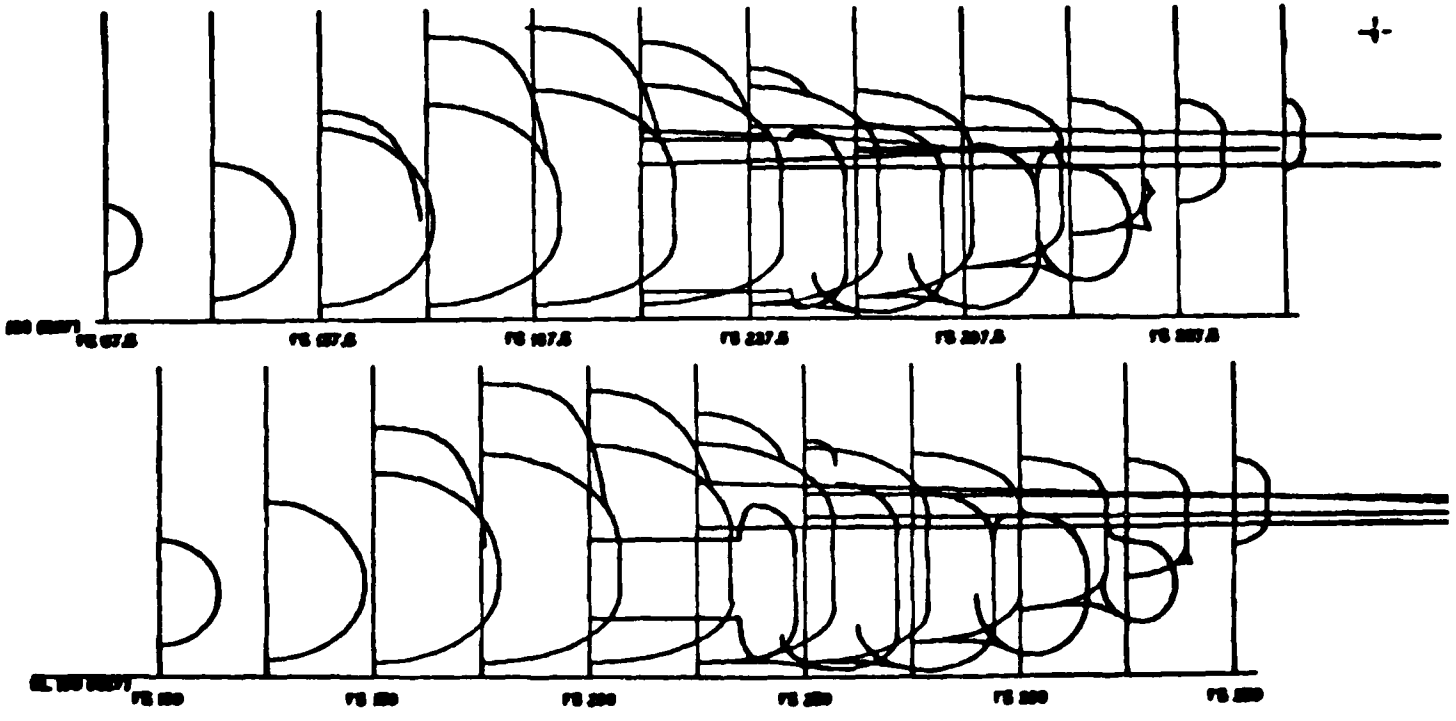


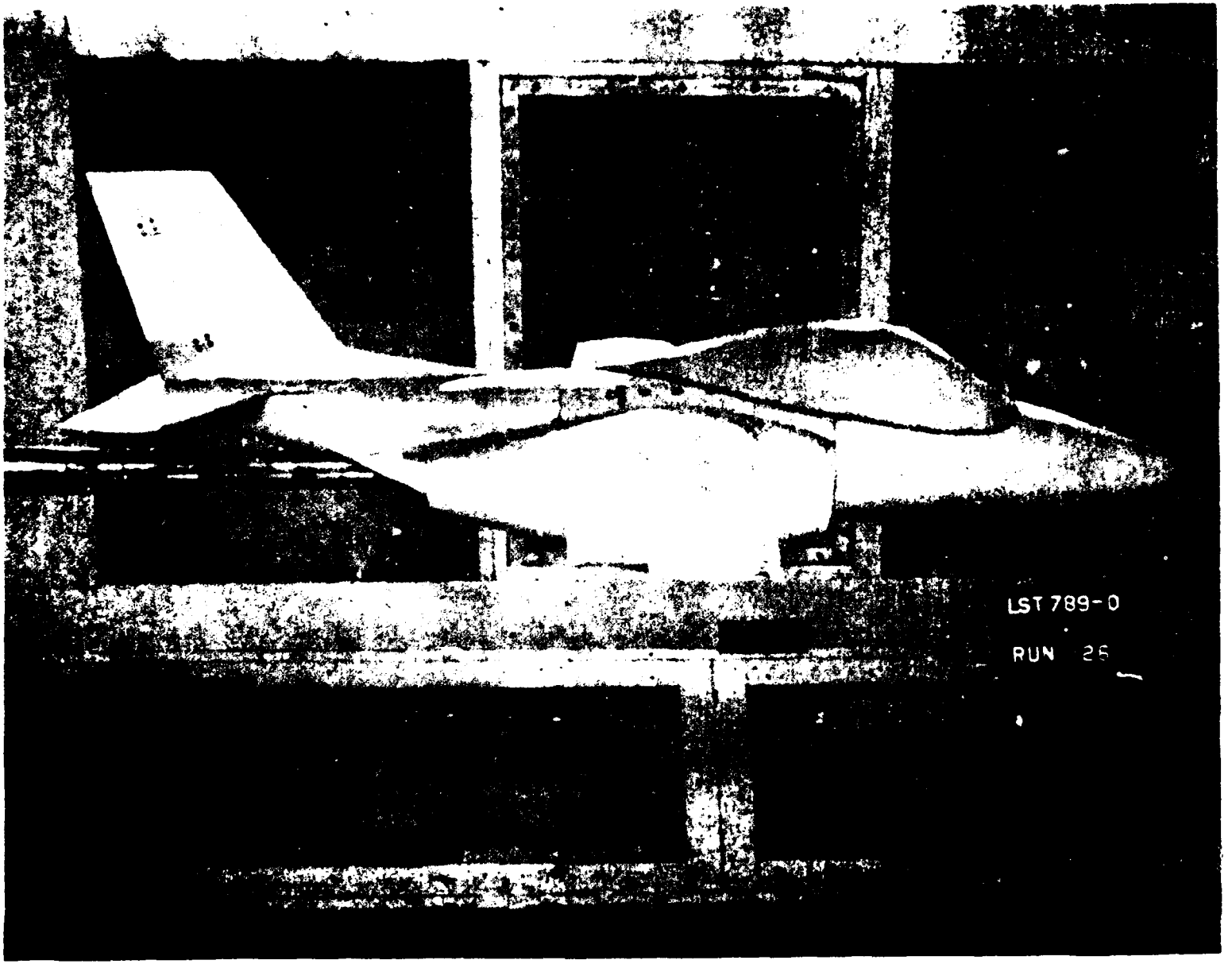
RHO CONIC SURFACE
WITH VARIABLE EDGE SLOPES

COMPLETE 3-D MODEL

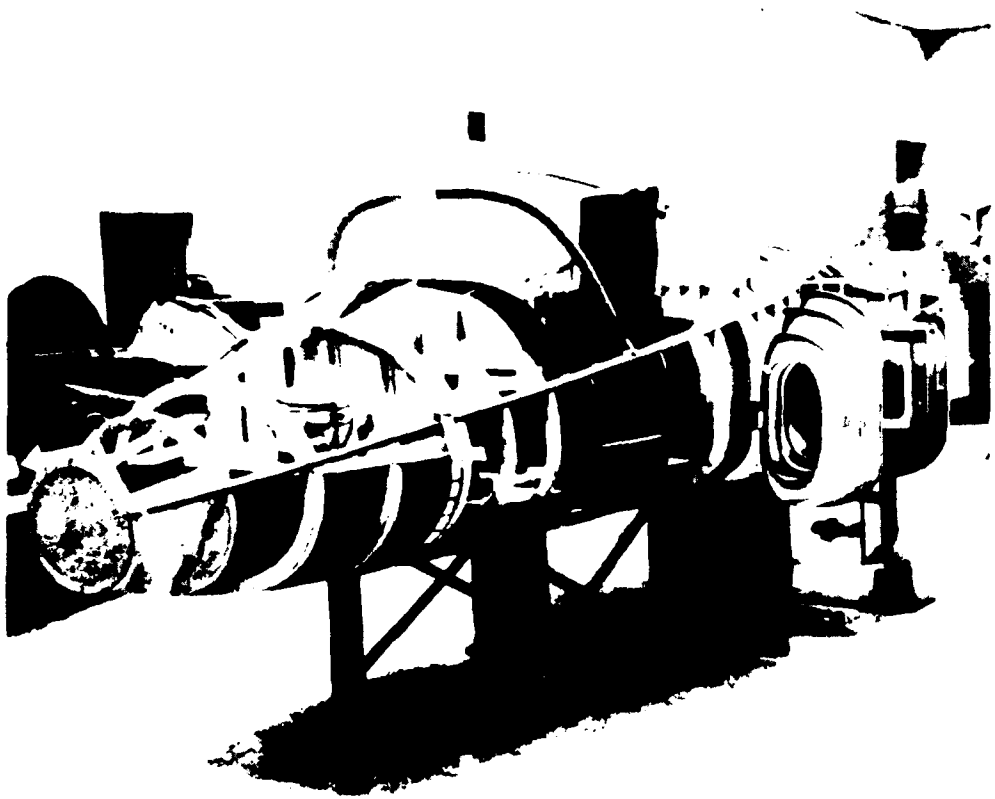


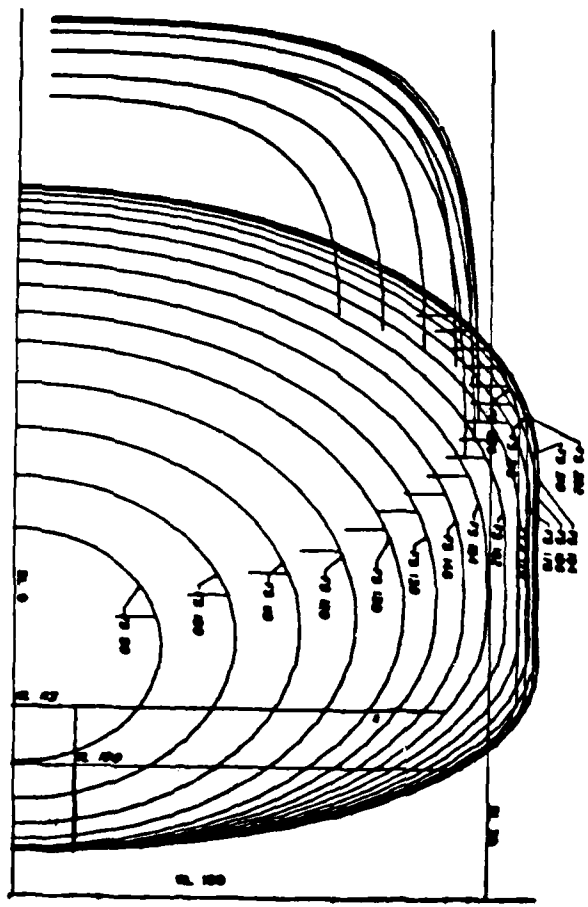
WIND TUNNEL MODEL CROSS SECTIONS



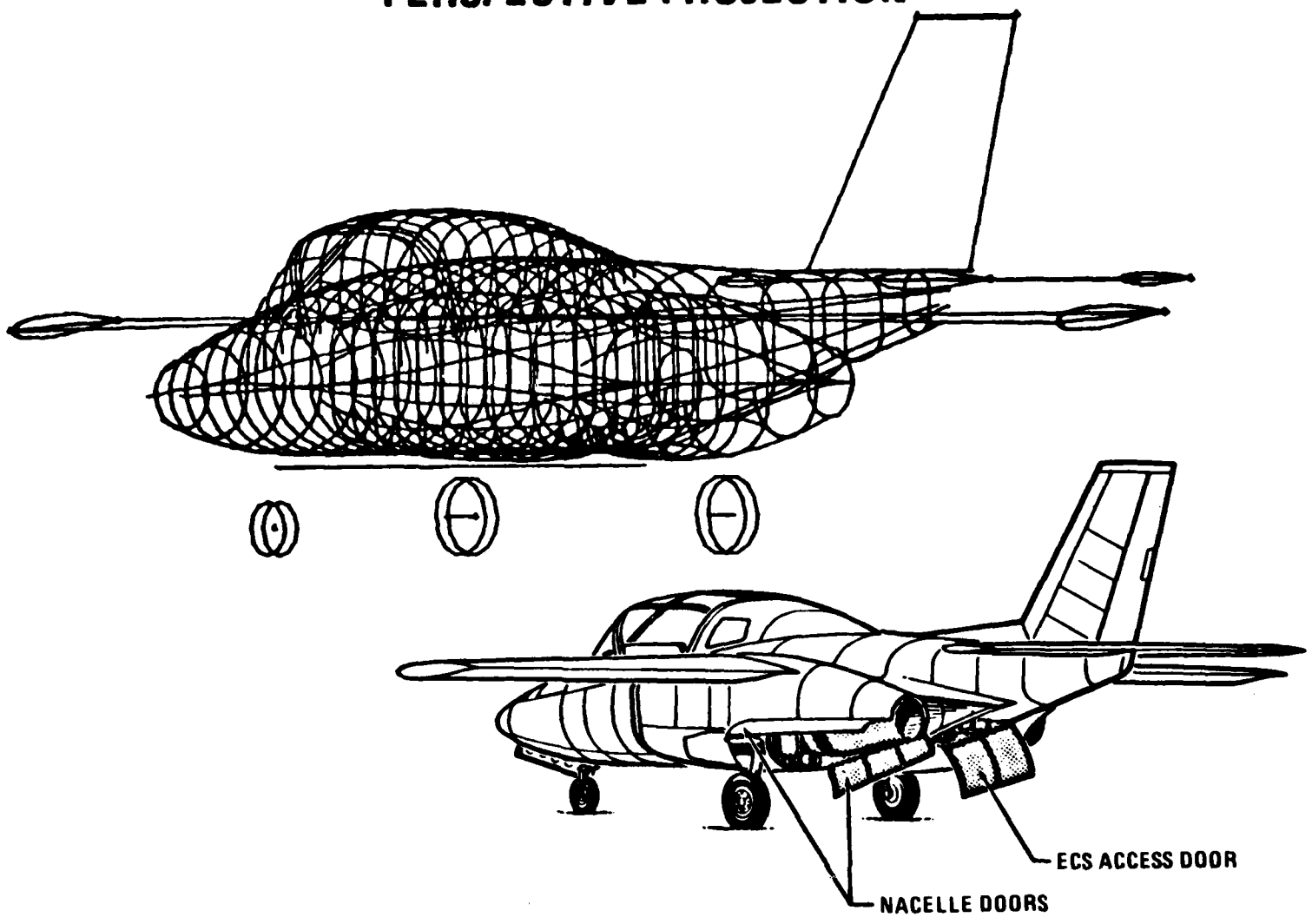

LST 789-0
RUN 25

FULL SCALE MOCKUP SECTIONS

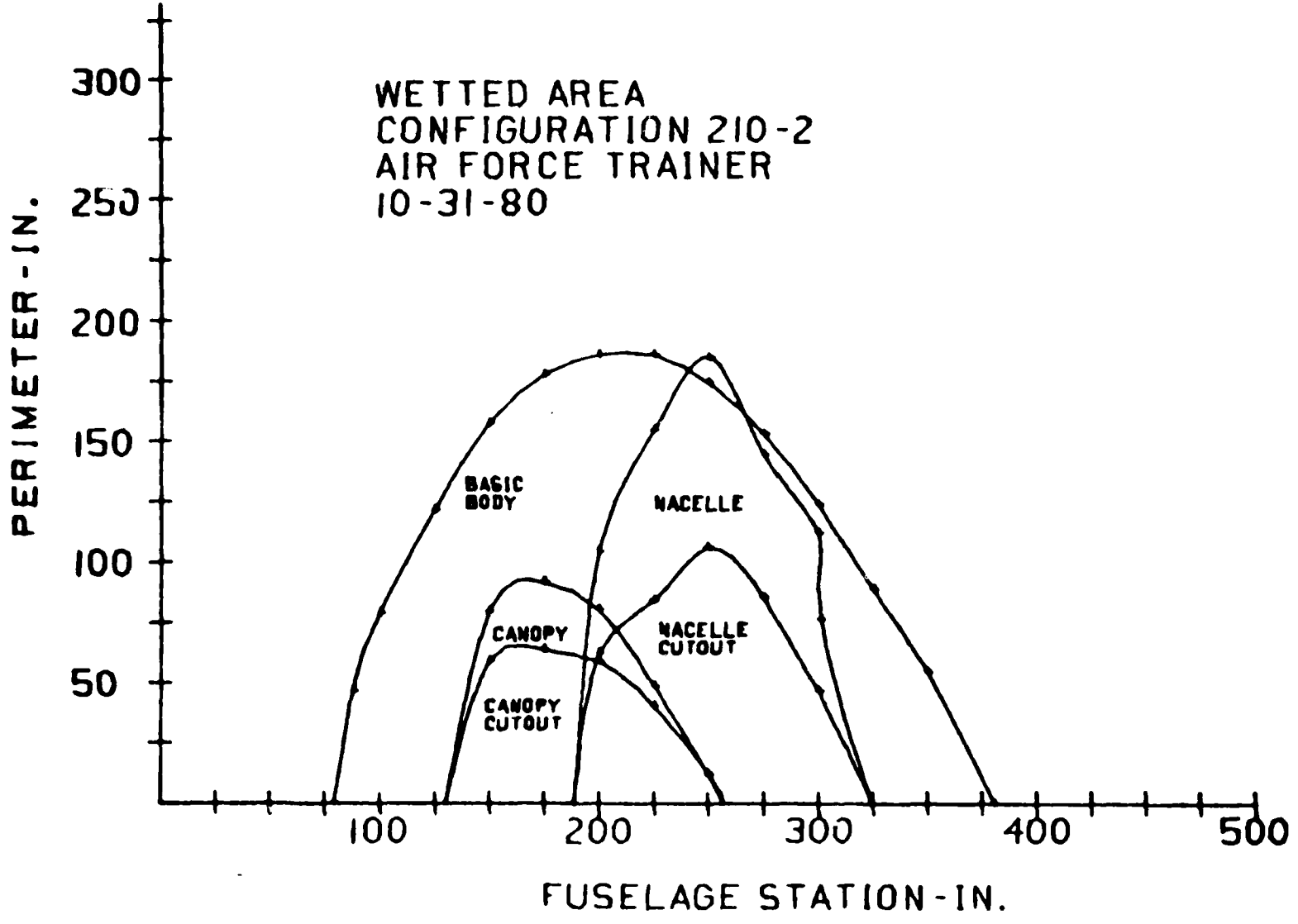




PERSPECTIVE PROJECTION

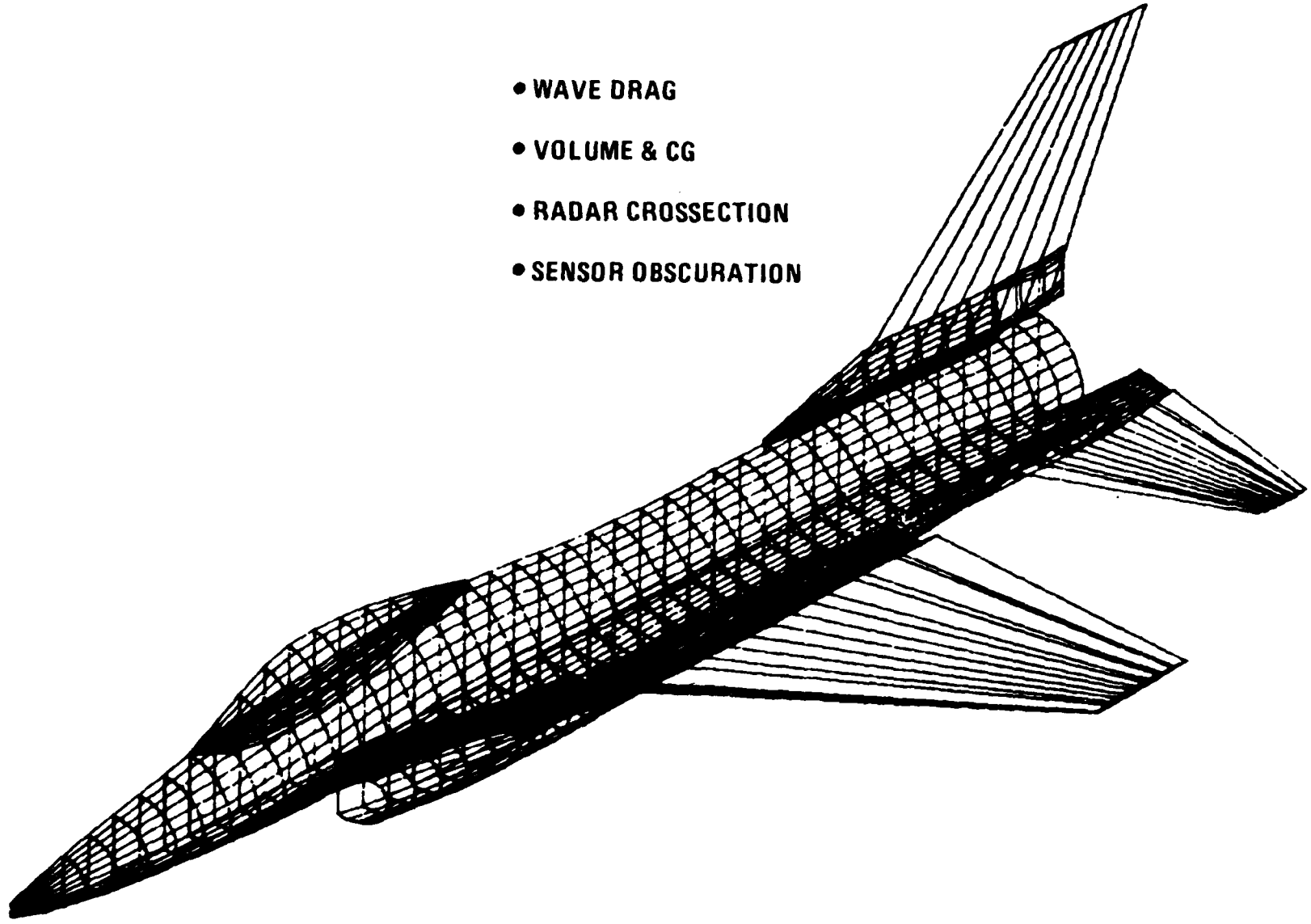


WETTED AREA PLOTS

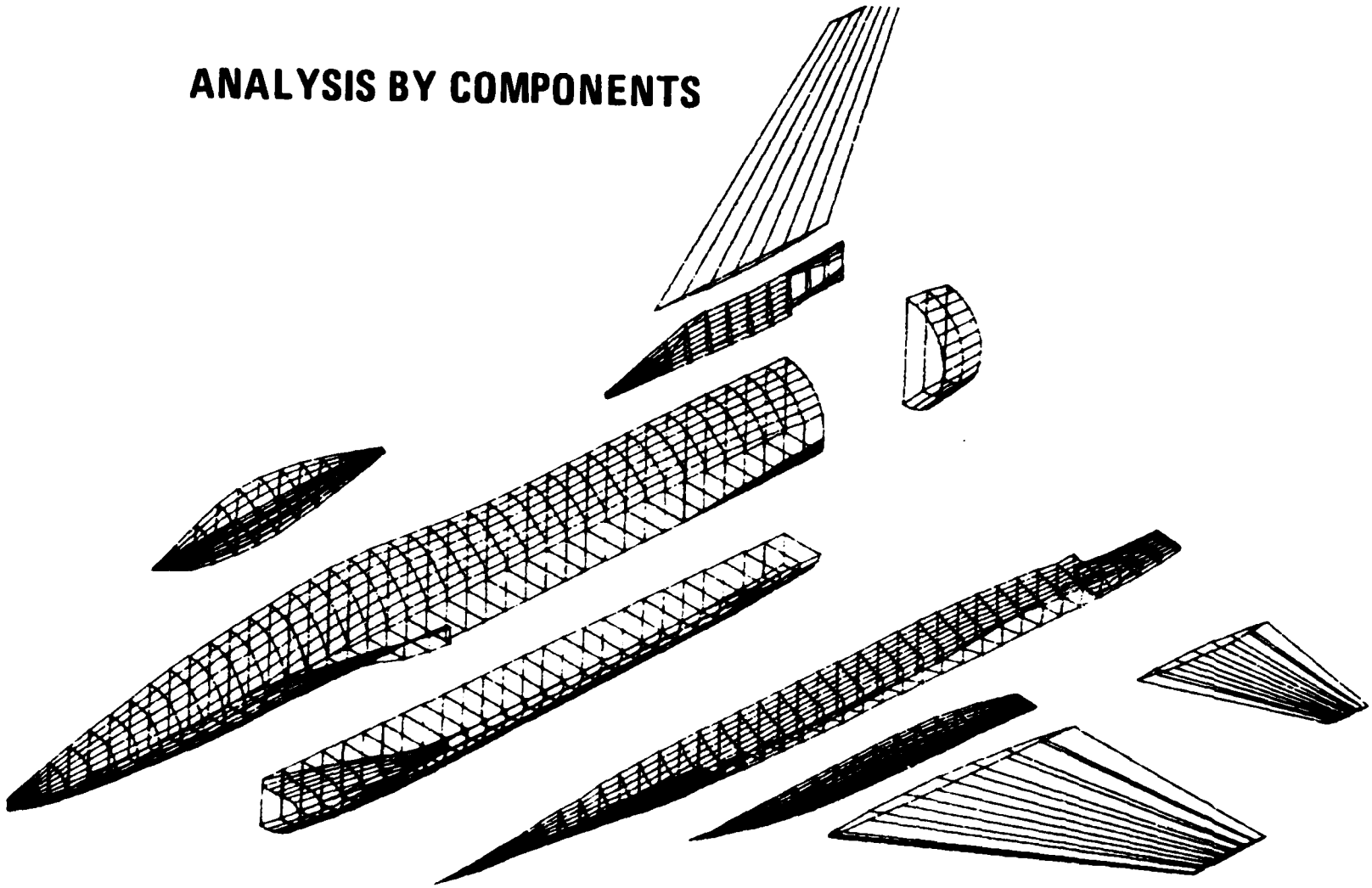


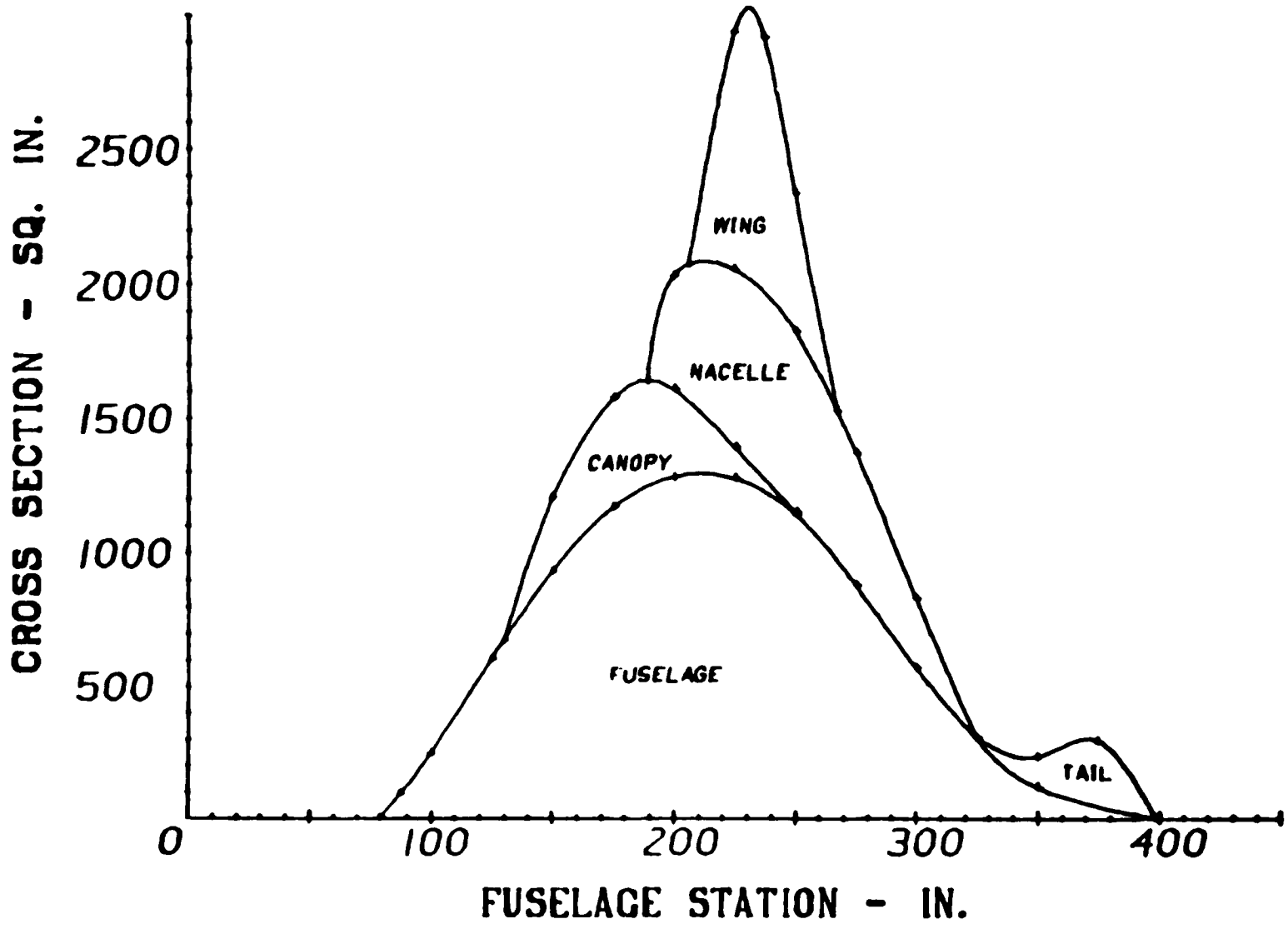
ANALYSIS MODELING

- WAVE DRAG
- VOLUME & CG
- RADAR CROSSECTION
- SENSOR OBSCURATION

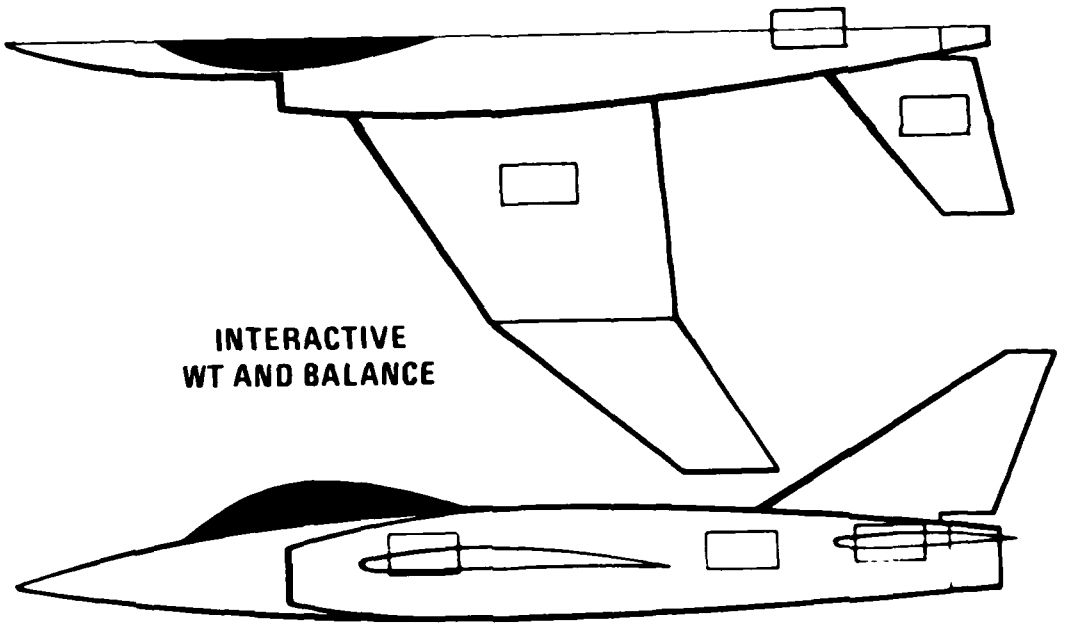


ANALYSIS BY COMPONENTS

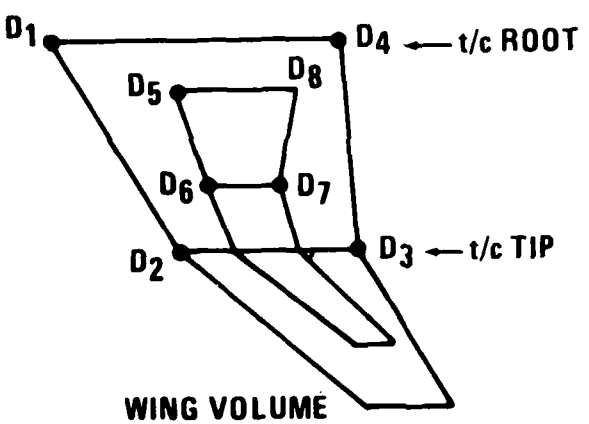



CROSS-SECTION AREA PLOTS
CROSS SECTION - SQ. IN.
2500
2000
1500
1000
500
0
100
200
300
400
WING
NACELLE
CANOPY
FUSELAGE
TAIL
FUSELAGE STATION - IN.

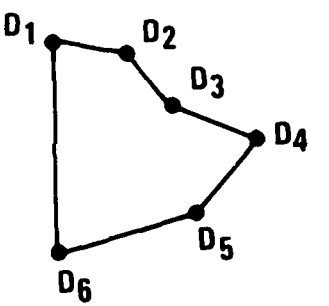
INTERACTIVE ANALYSIS FOR MANY PURPOSES



INTERACTIVE
WT AND BALANCE

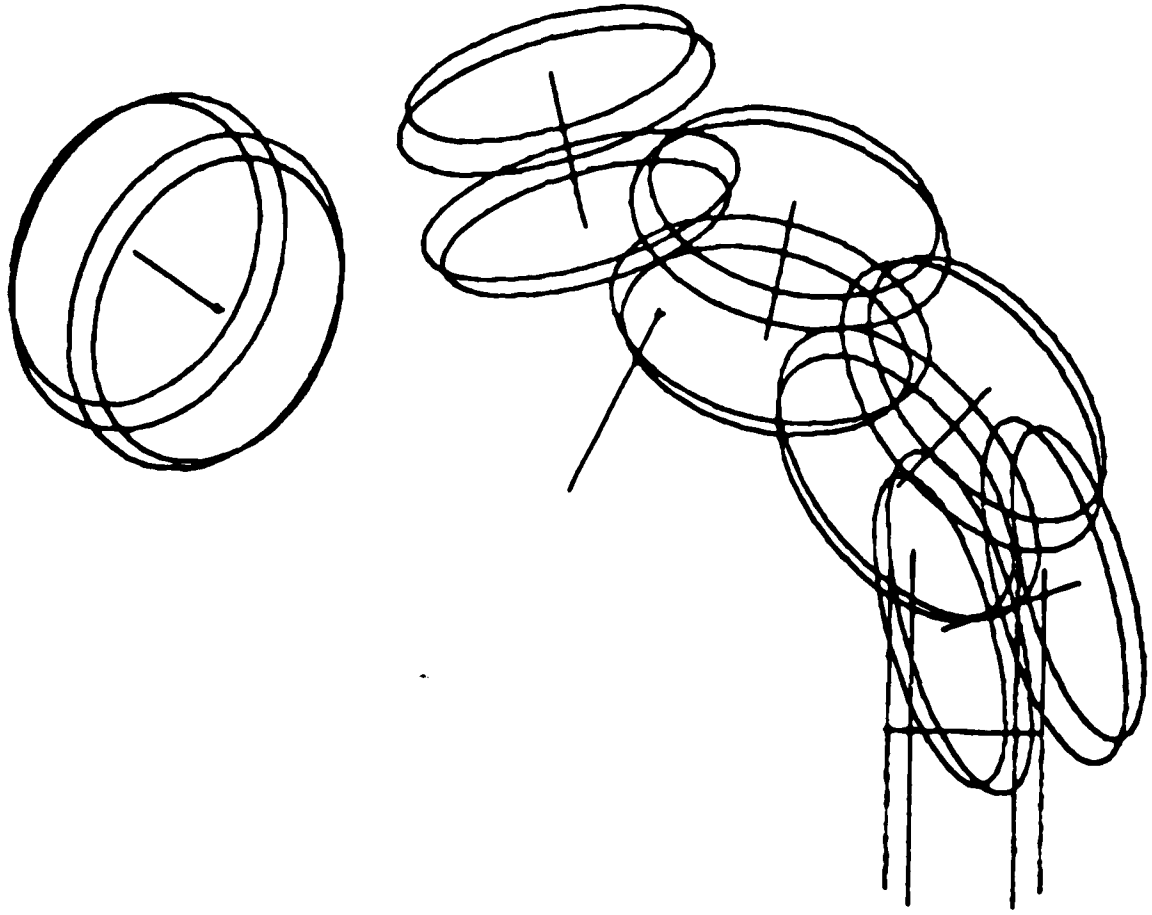


WING VOLUME

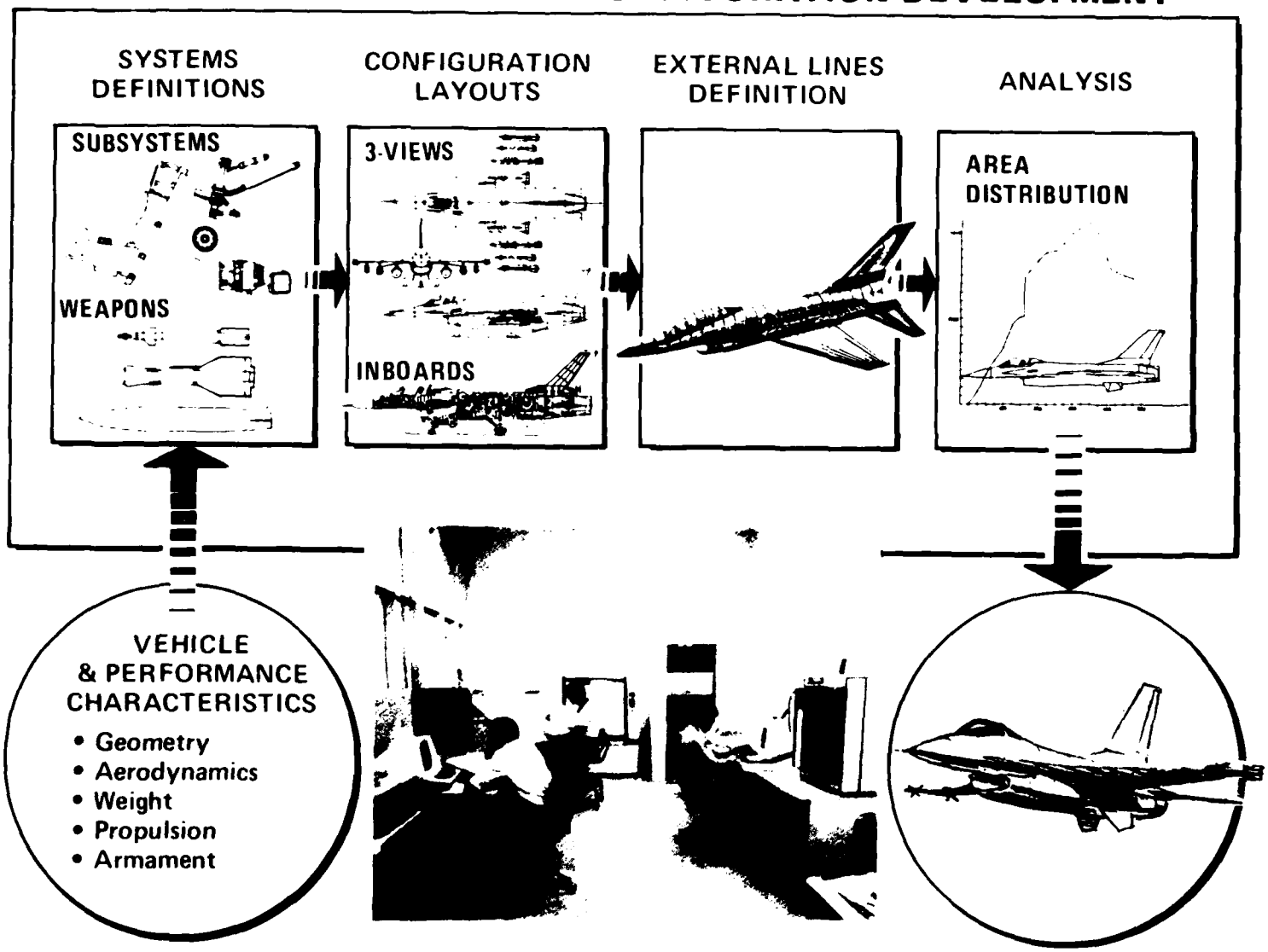


CROSSECTIONAL
AREA

EXAMPLE OF LANDING GEAR MOTION



INTERACTIVE GRAPHICS IN CONFIGURATION DEVELOPMENT



MILITARY AIRCRAFT CONCEPTUAL DESIGN TRENDS FOR THE 80's

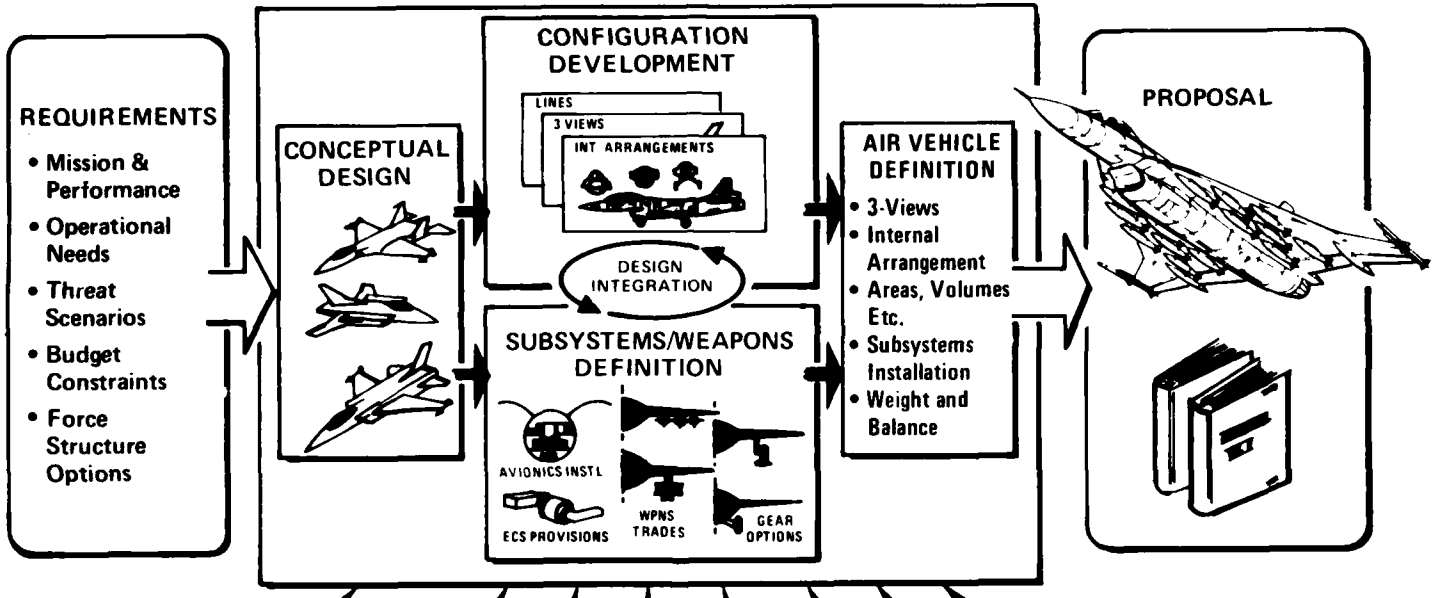
S. Keith Jackson
General Dynamics
Ft. Worth, Texas

MILITARY AIRCRAFT CONCEPTUAL DESIGN TRENDS FOR THE 80'S

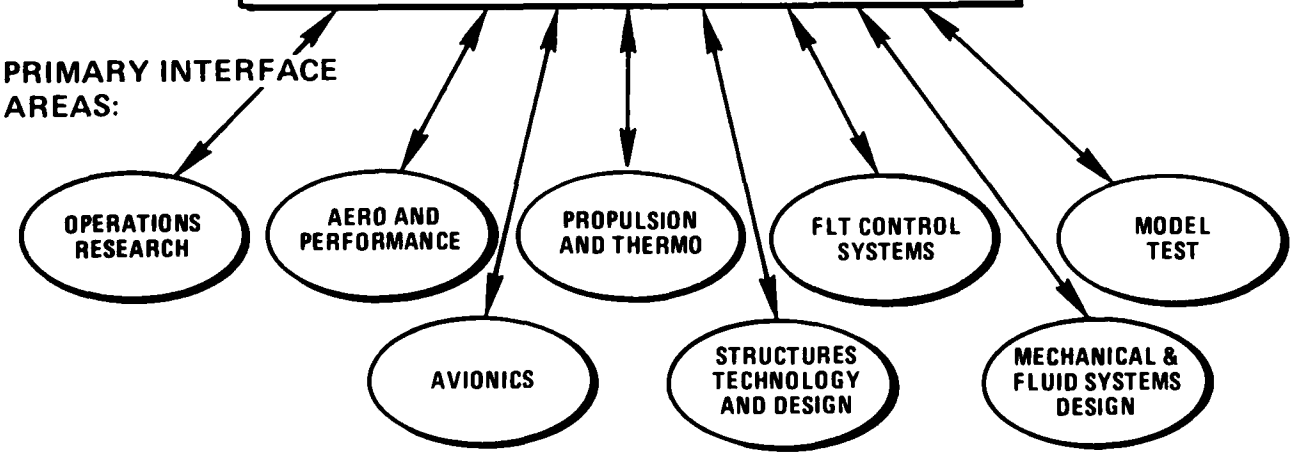
- OVERVIEW OF RECENT TRENDS
- THE EVOLVING CONCEPTUAL DESIGN PROCESS
- ANALYTICAL TOOLS
  - SCREENING ANALYSES
  - THE CONCEPTUAL DESIGN SYNTHESIS PROCEDURE
  - EFFECTIVENESS MODELS

THE ADVANCED DESIGN PROCESS

BASIC PROCESS:



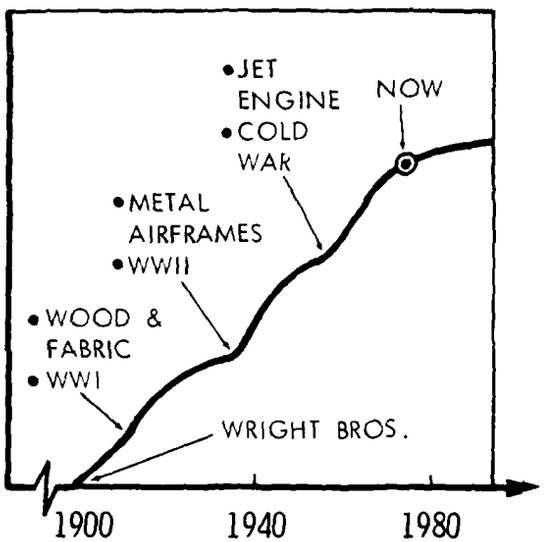
PRIMARY INTERFACE AREAS:



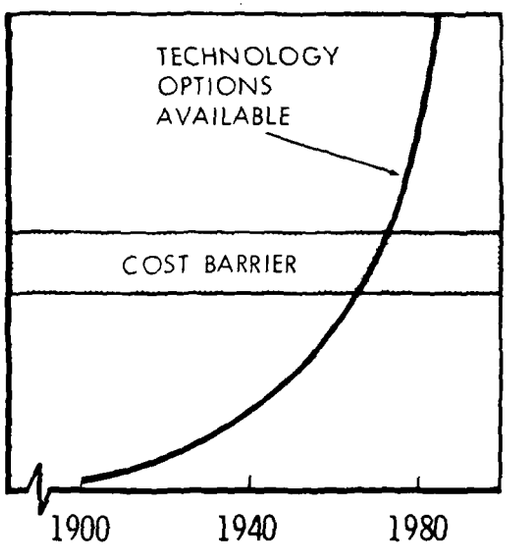
B40890

THE WORLD IS CHANGING

DEGREE OF DEVELOPMENT OF MAJOR AIRFRAME TECHNOLOGIES
- Aero
- Propulsion
- Structure



NUMBER OF IMPORTANT TECHNOLOGICAL OPTIONS



INDIVIDUAL AIRFRAME TECHNOLOGIES ARE APPROACHING MATURITY

BUT

OVERALL OPTIONS ARE INCREASING RAPIDLY . . . ARE COST CONSTRAINED

RESULT: A SHIFTING EMPHASIS IN CONCEPTUAL DESIGN

FW 76 274 VG 5851
6 APRIL 76

THE SHIFTING EMPHASIS

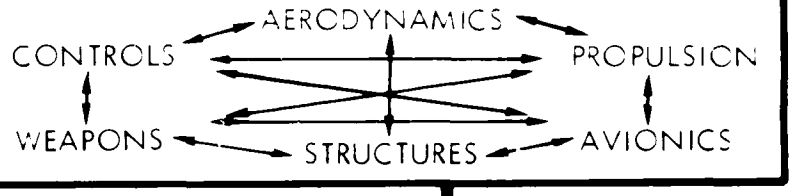
IN THE PAST

- AIRCRAFT TENDED TO BE BUILT AROUND "INDIVIDUAL" TECHNOLOGIES
  - High HP Wt Int. Combustion Eng.
  - Metal-Monocoque Structures
  - Jet Engine
  - Supersonic Aerodynamics

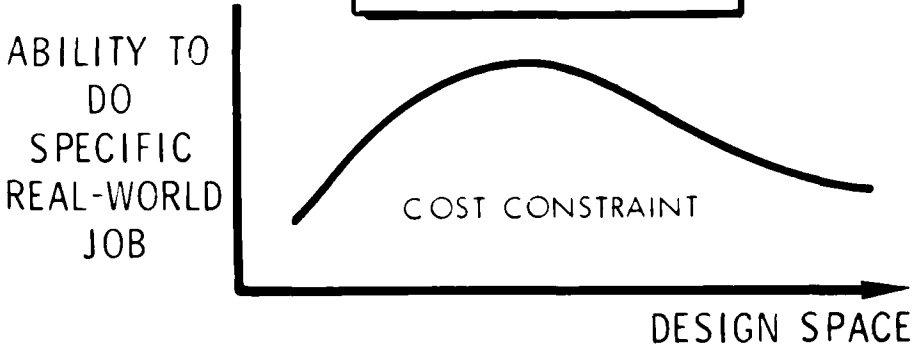
→ PERFORMANCE EMPHASIS

IN THE FUTURE

- GAINS INCREASINGLY FROM "MULTIDISCIPLINARY" CROSS-COUPLING OF TECHNOLOGIES

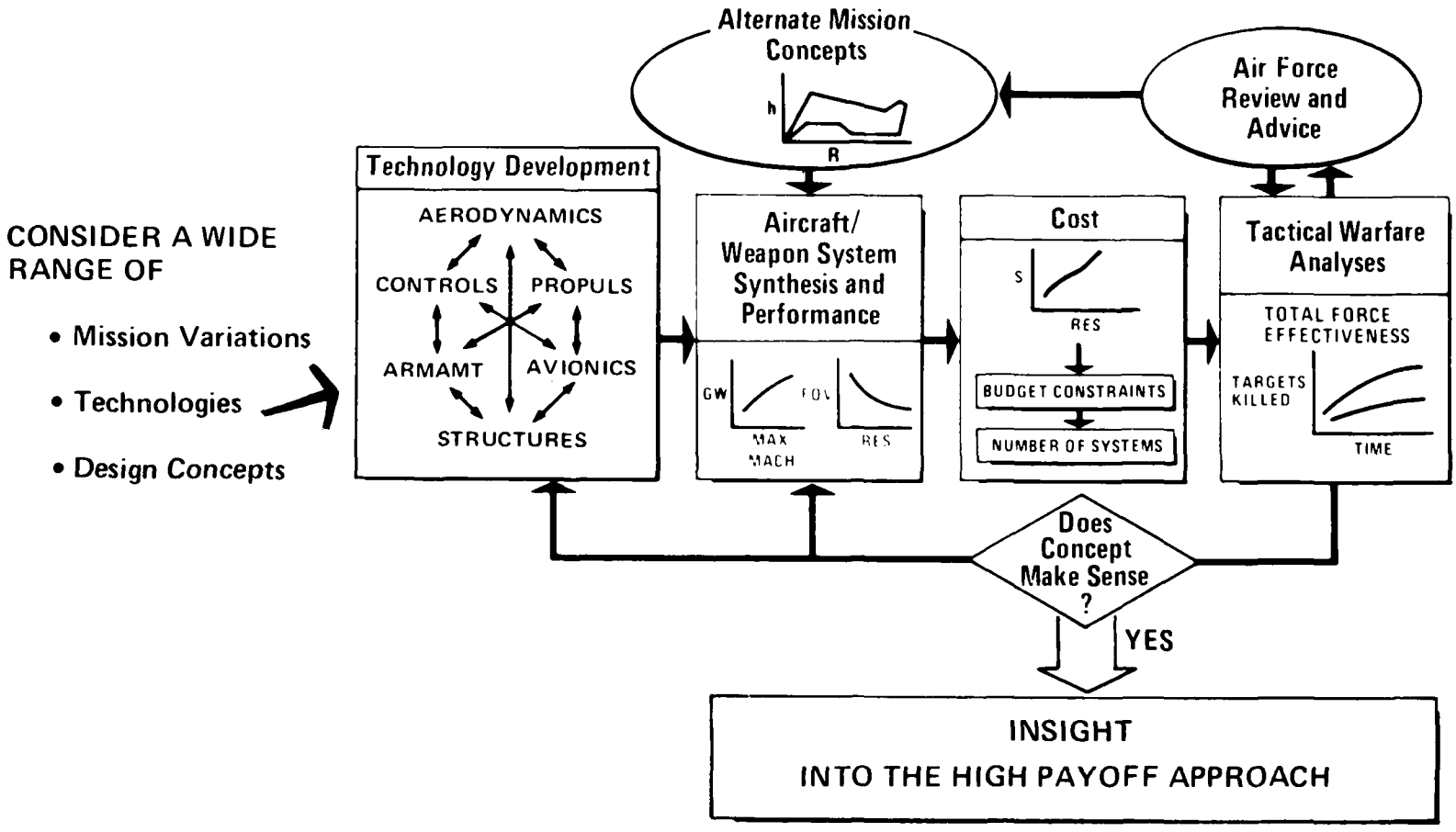


→ JOB EMPHASIS



6B5852B

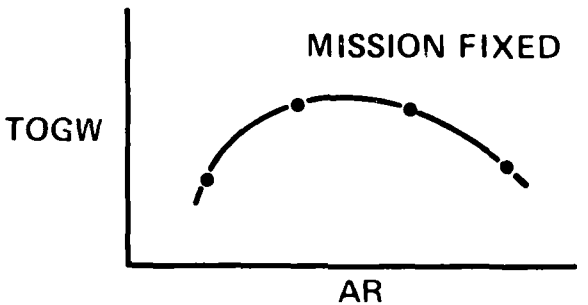
OUR APPROACH



B8869B

THE PROBLEM WITH DATA

- A MINIMUM OF 3 TO 5 "AIRPLANES" ARE NEEDED TO DEFINE A SINGLE-VARIABLE OPTIMUM . . .



- AND THERE ARE A LOT OF VARIABLES

MISSION	MAJOR DESIGN	ENGINE	PAYLOAD	SCENARIO
• Range	• Thrust	• BPR	• Radar	• Threat Types
• Payload	• S	• OPR	• EO	• Threat Numbers
• Combat Allowance	• AR	• T.I.T.	• ECM	• Threat Tech
• $M_{Max.}$	• t/c	• θ Break	• Crew Size	• Target Types
• M_{Cruise}	• λ	• Tech Level	• Gun	• Target Numbers
• G Capability	• Λ LE	• Thrust Rev?	• "Armor"	• Weather
• T.O. Dist	• l_f	• Component Eff.		• Support Forces
• Land Dist	• Tail Location/Type			• Tactics
• Accel Time	• No. Engines			
	• Stealth Shaping			
	• Inlet			
	• Nozzle			
	• Equipment Tech.			

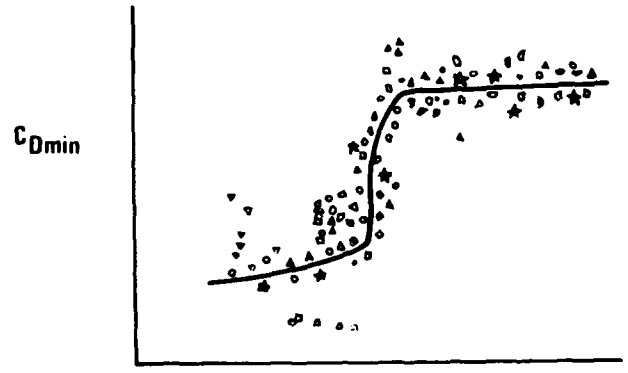
6R2029A

CONCEPTUAL
DESIGN
SYNTHESIS
PROCEDURE

CDSP

A WORD ON ACCURACY

F-16 MINIMUM DRAG
FLIGHT TEST DATA



- "ABSOLUTE" ACCURACY IS <u>OFTEN</u> . . . .
  - AN ILLUSION
  - EXPENSIVE
  - TIME CONSUMING
  - ⇩
  - COUNTERPRODUCTIVE
- BUT SMALL <u>DIFFERENCES</u> CAN STILL BE IMPORTANT

- MANY CONCEPTUAL/PRELIMINARY DESIGN PROBLEMS ARE BY NATURE IMPRECISE
- MOST IMPORTANT ERRORS COME FROM
  - NEGLECTING CRUCIAL VARIABLES
  - BAD INPUT DATA
  - LACK OF FEEL FOR THE ANSWER
- ENORMOUS TEMPTATION TO BE RESISTED (HOWEVER IMPERFECTLY)
  - DOING WHAT YOU KNOW HOW TO DO – IN ULTIMATE DETAIL, WHILE . . .
  - NEGLECTING ENTIRELY WHAT YOU DON'T KNOW EXACTLY HOW TO DO
- THINKING POINTS – WHEN DO I NEED:
  - COMPREHENSIVENESS? • SENSITIVITY? • ACCURACY? • PRECISION?
  - RESPONSE TIME?

⇨ CONCEPTUAL/PRELIMINARY DESIGN NEEDS OFTEN VERY DIFFERENT FROM THOSE OF DETAIL DESIGN

B27116

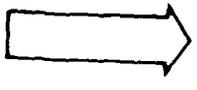
CDSP – PHILOSOPHICAL BACKGROUND

NEEDS

- EFFICIENCY
  - CHEAP ENOUGH FOR BROAD SURVEYS
- GOOD TRENDS FOR BOTH CURRENT AND ADVANCED TECHNOLOGY
- FLEXIBILITY (BUT NOT AT THE EXPENSE OF EFFICIENCY)
- RETAIN DESIGNER AS INTEGRAL PART OF CONFIGURATION DEVELOPMENT PROCESS

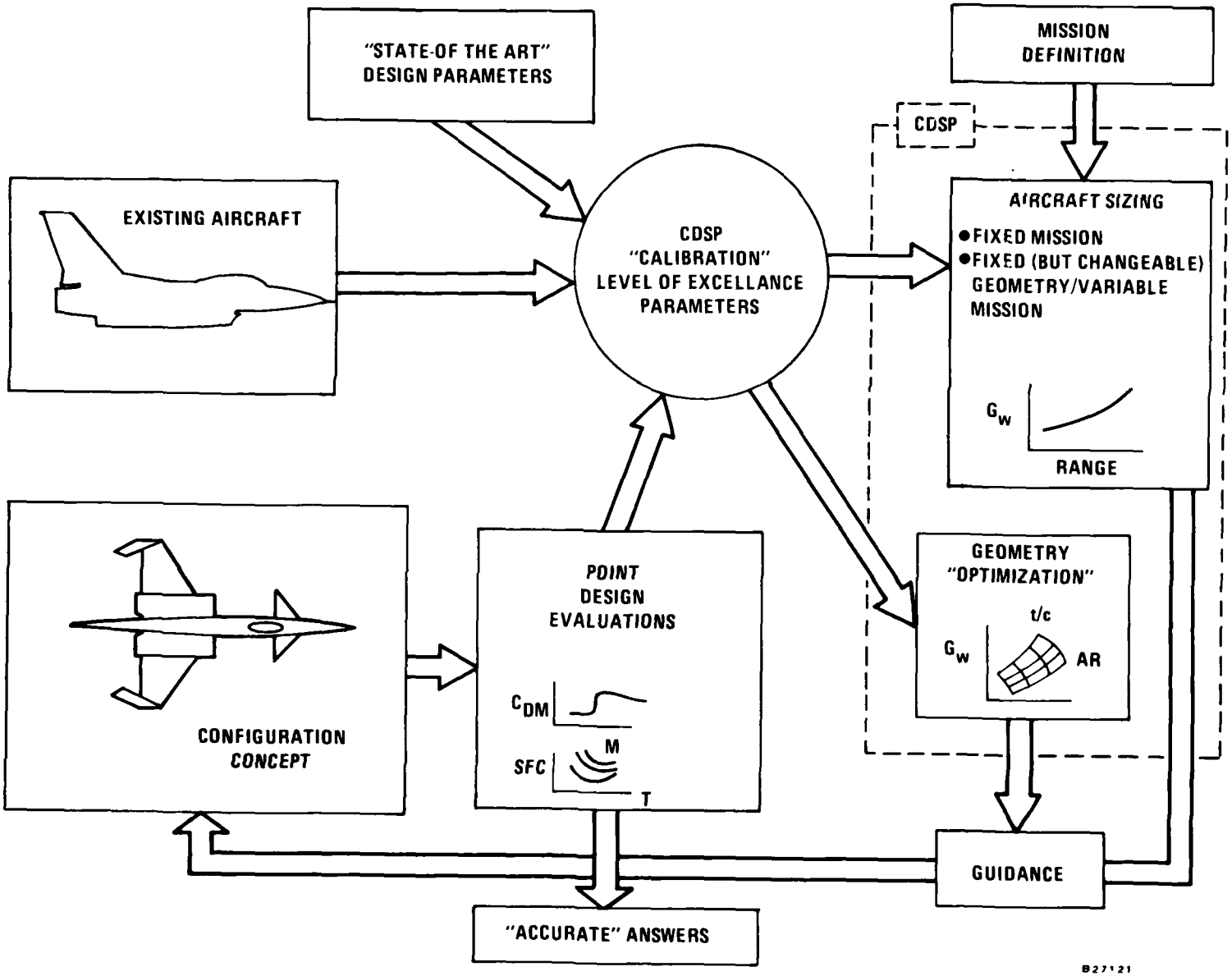
APPROACH

- METHODS OPTIMIZED FOR CONCEPTUAL DESIGN
- "ACCURACY" ONLY WHERE NECESSARY
  - RESOLUTION OF DIFFERENCES
  - ABSOLUTE LEVELS BY CALIBRATION TO KNOWN BASELINE
- VARIATIONS ANALYTICALLY (NOT STATISTICALLY) BASED
  - "ENVELOPE" PHYSICS
  - WELL-DESIGNED AIRPLANE
  - LEVEL-OF-EXCELLENCE PARAMETERS



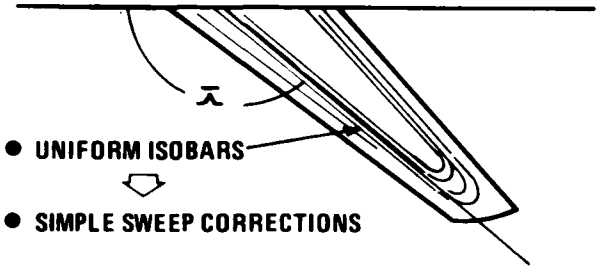
CLEAR DESIGN & TECHNOLOGY QUALITY INDICATIONS

THE CONCEPTUAL DESIGN SYNTHESIS PROCEDURE



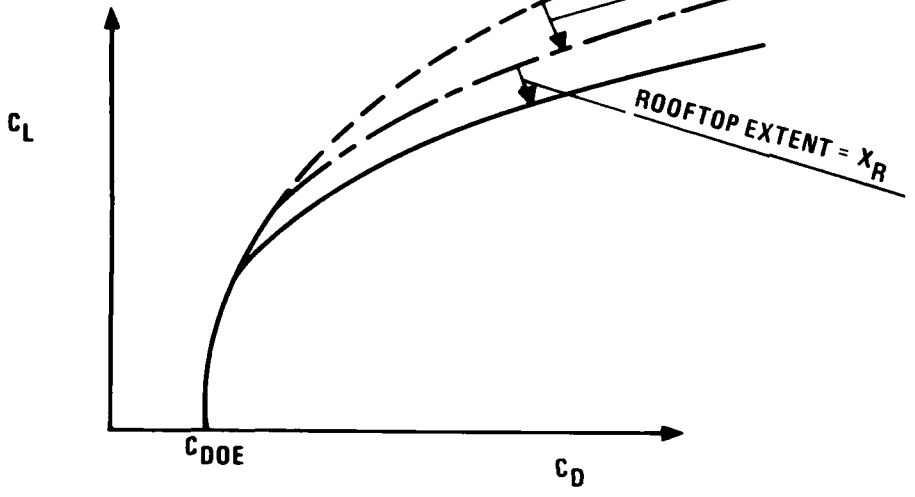
ENVELOPE PHYSICS – AN EXAMPLE – TRANSONIC DRAG DUE TO LIFT

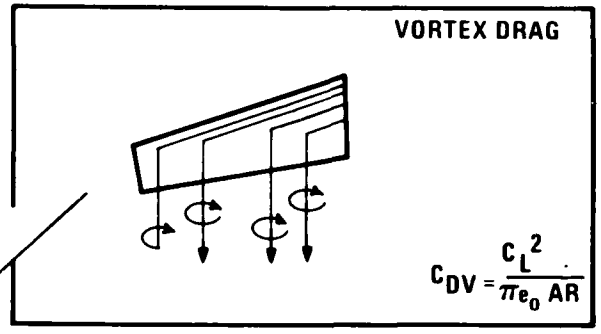
- A GOOD DESIGN

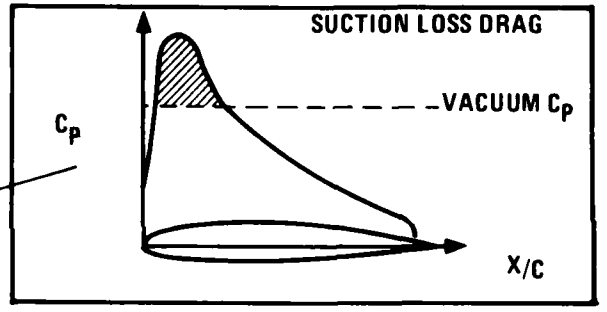


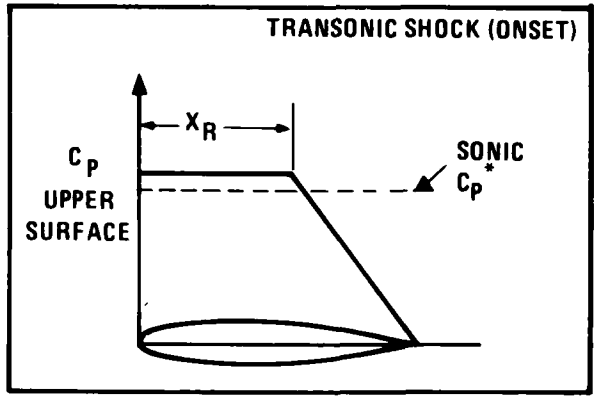
- UNIFORM ISOBARS
- SIMPLE SWEEP CORRECTIONS

$M_{\infty n} = M_\infty \cos^n \Lambda$









"CALIBRATION" PARAMETERS e_0, C_{Li}, X_R EACH HAVE PHYSICAL MEANING

B27122

CDSP SUMMARY OUTPUT

SUMMARY DATA PAGE 1

	CONFIGURATION NUMBER	1	2	3	4	5	6	7	8	9	10
1	DASH MACH NUMBER	1.6000	1.6000	1.6000	1.6000	1.6000	1.6000	1.6000	1.6000	1.6000	1.6000
2	DASH ALTITUDE (FT)	56656.	56694.	56298.	55873.	57177.	56810.	56401.	57603.	57274.	56895.
3	DASH RADIUS (NMI)	200.	200.	200.	200.	200.	200.	200.	200.	200.	200.
4	FUSELAGE LENGTH (FT)	63.7928	63.8118	64.7491	65.9368	62.8055	63.6730	64.7438	61.9789	62.6949	63.6472
5	WING AREA (SQFT)	850.	850.	850.	850.	900.	900.	900.	950.	950.	950.
6	LE SWEEP (DEG)	35.0000	35.0000	35.0000	35.0000	35.0000	35.0000	35.0000	35.0000	35.0000	35.0000
7	T/C PARALLEL	.0300	.0300	.0300	.0300	.0300	.0300	.0300	.0300	.0300	.0300
8	WING ASPECT RATIO	3.0000	3.0000	3.0000	3.0000	3.0000	3.0000	3.0000	3.0000	3.0000	3.0000
9	ENGINE SCALE FACTOR	1.8000	1.8000	2.0000	2.2000	1.8000	2.0000	2.2000	1.8000	2.0000	2.2000
10	RESIZED FUS LGTH(FT)	63.7528	63.8118	64.7491	65.9368	62.8055	63.6730	64.7438	61.9789	62.6949	63.6472
11	MEAN SWEEP (DEG)	24.2731	24.2731	24.2731	24.2731	24.2731	24.2731	24.2731	24.2731	24.2731	24.2731
12	T/C NORMAL	.0309	.0309	.0309	.0309	.0309	.0309	.0309	.0309	.0309	.0309
13	GROSS WEIGHT (LBS)	71119.	71125.	73437.	76020.	71871.	74136.	76599.	72802.	74920.	77268.
14	FUEL WEIGHT (LBS)	26646.	26647.	27380.	28339.	26960.	27654.	28509.	27427.	27999.	28755.
15	WING WEIGHT (LBS)	6852.	6893.	7014.	7147.	7224.	7347.	7478.	7563.	7681.	7812.
16	THRUST / WEIGHT T/W	.8732	.8731	.9396	.9984	.8641	.9307	.9909	.8530	.9210	.9823
17	WING LOADING W/S	83.6699	83.6764	86.3964	89.4356	79.8568	82.3739	85.1100	76.6341	78.8630	81.3346
18	MISSION RADIUS (NMI)	522.	522.	522.	522.	522.	522.	522.	522.	522.	522.
19	LOAD FACTOR 1 (G'S)	2.4924	2.4917	2.3620	2.2477	2.5705	2.4219	2.3046	2.6500	2.4915	2.3663
20	MAX LOAD FACTOR 1	8.6900	8.6872	7.5555	6.6759	9.3896	8.1020	7.1464	10.1253	8.7014	7.6483
21	TURN RATE 1 (DPS)	2.7123	2.7114	2.5423	2.3916	2.8133	2.6206	2.4668	2.9156	2.7112	2.5479
29	SPECIFIC POWER (FPS)	420.	420.	480.	536.	405.	466.	522.	390.	450.	507.
30	ACCEL TIME (SEC)	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
31	FERRY RANGE (NMI)	2727.	2727.	2598.	2493.	2797.	2664.	2552.	2875.	2732.	2613.
32	FERRY FUEL (LBS)	30526.	30529.	33325.	36357.	29946.	32633.	35513.	29465.	32040.	34783.
33	T O OVER 50 FT (FT)	2523.	2523.	2396.	2317.	2452.	2324.	2239.	2401.	2265.	2174.
34	LAND OVER 50 FT (FT)	2654.	2654.	2727.	2807.	2577.	2646.	2720.	2510.	2574.	2642.
35	LAND OVER 50 REV(FT)	2384.	2384.	2411.	2447.	2306.	2331.	2362.	2240.	2260.	2287.
36	T O GROUND RUN (FT)	1677.	1678.	1567.	1495.	1624.	1512.	1437.	1586.	1468.	1388.
37	LAND GROUND ROLL(FT)	1922.	1922.	1984.	2050.	1862.	1920.	1982.	1810.	1863.	1921.
38	LAND GRD ROLL REV(FT)	1652.	1652.	1667.	1690.	1591.	1604.	1624.	1540.	1550.	1565.
39	TO OVR 50 TV ABE(FT)	1113.	1113.	938.	810.	1057.	925.	793.	1094.	918.	784.
40	AVG UNIT PROCURE($M)	11.4760	11.4766	11.7386	11.9987	11.5331	11.7938	12.0512	11.5941	11.8508	12.1055
41	ROTE COST ($M)	2773.	2773.	2856.	2941.	2759.	2881.	2965.	2826.	2907.	2989.
42	AVE UNIT FGP SCO($M)	17.0216	17.0226	17.4516	17.8798	17.1303	17.5568	17.9803	17.2461	17.6654	18.0842
43	FUEL COST ($M)	4.7747	4.7750	5.2170	5.6725	4.7400	5.1757	5.6218	4.7138	5.1411	5.5795
44	AVG LIFE CY CST ($M)	34.2804	34.2821	35.3753	36.4826	34.4079	35.4910	36.5820	34.5545	35.6187	36.6951
45	TOTAL FORCE SIZE	683.	683.	656.	630.	690.	653.	628.	676.	650.	625.
46	TO GRD RUN TV ABE(FT)	754.	754.	612.	513.	742.	602.	497.	739.	597.	491.
52	LOADFACTOR T1 (G'S)	3.3886	3.3883	3.4533	3.4911	3.4541	3.5272	3.5746	3.5034	3.5946	3.6491
53	TURN RATE T1 (DPS)	6.6596	6.6590	6.7988	6.8801	6.8004	6.9575	7.0592	6.9063	7.1019	7.2185
54	LOADFACTOR T2 (G'S)	3.3886	3.3883	3.4533	3.4911	3.4541	3.5272	3.5746	3.5034	3.5946	3.6491
55	LOADFACTOR T3 (G'S)	3.6822	3.6820	3.8662	4.0074	3.6987	3.8944	4.0490	3.7010	3.9119	4.0796
56	ACCEL TIME (SEC)	76.1546	76.1527	65.5944	58.1992	79.6389	68.0826	60.0437	83.5774	70.8536	62.1014
57	MAX MACH NO.	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
58	MISSION ITERATIONS	3.	4.	4.	4.	3.	4.	4.	5.	3.	3.
59	SIZING ITERATIONS	3.	4.	4.	4.	3.	4.	4.	5.	3.	3.
60	CONDITION CODE	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.

B42184

CDSP OUTPUT-AERODYNAMICS

AERODYNAMIC CHARACTERISTICS

CD MIN SUBSONIC= .01059
K SUBSONIC= .14276
L/D MAX SUBSONIC= 12.45692
CL AT MAX SUBSONIC L/D= .27243
COUTEE MACH= .85004
COUTEE CL= .24223
COUTEE L/D= 12.75647
MAX SUBSONIC CL AT .9M= .56476
SUPERSONIC TRIM DRAG FACTOR= 1.0900
MAX WING MIN-WAVE-DRAG MACH= 1.20

AERODYNAMICS OPTION 6.

DRAG POLARS CD=CD0E+CDL (ADD CDST FOR STORES-IN) CDL=CDI+CDP+CDR

MACH = .300 CD0E = .0106 K = .1427

CL	CD	CDL	CDST	CDI	CDP	CDR	MOD
0.00000	.01059	0.00000	.00121	0.00000	0.00000	0.00000	.93474
.10000	.01202	.00142	.00121	.00141	.00001	0.00000	.93734
.20000	.01630	.00570	.00121	.00566	.00004	0.00000	.93837
.30000	.02342	.01282	.00121	.01273	.00010	0.00000	.93811

MACH = 1.200 CD0E = .0219 K = .2328

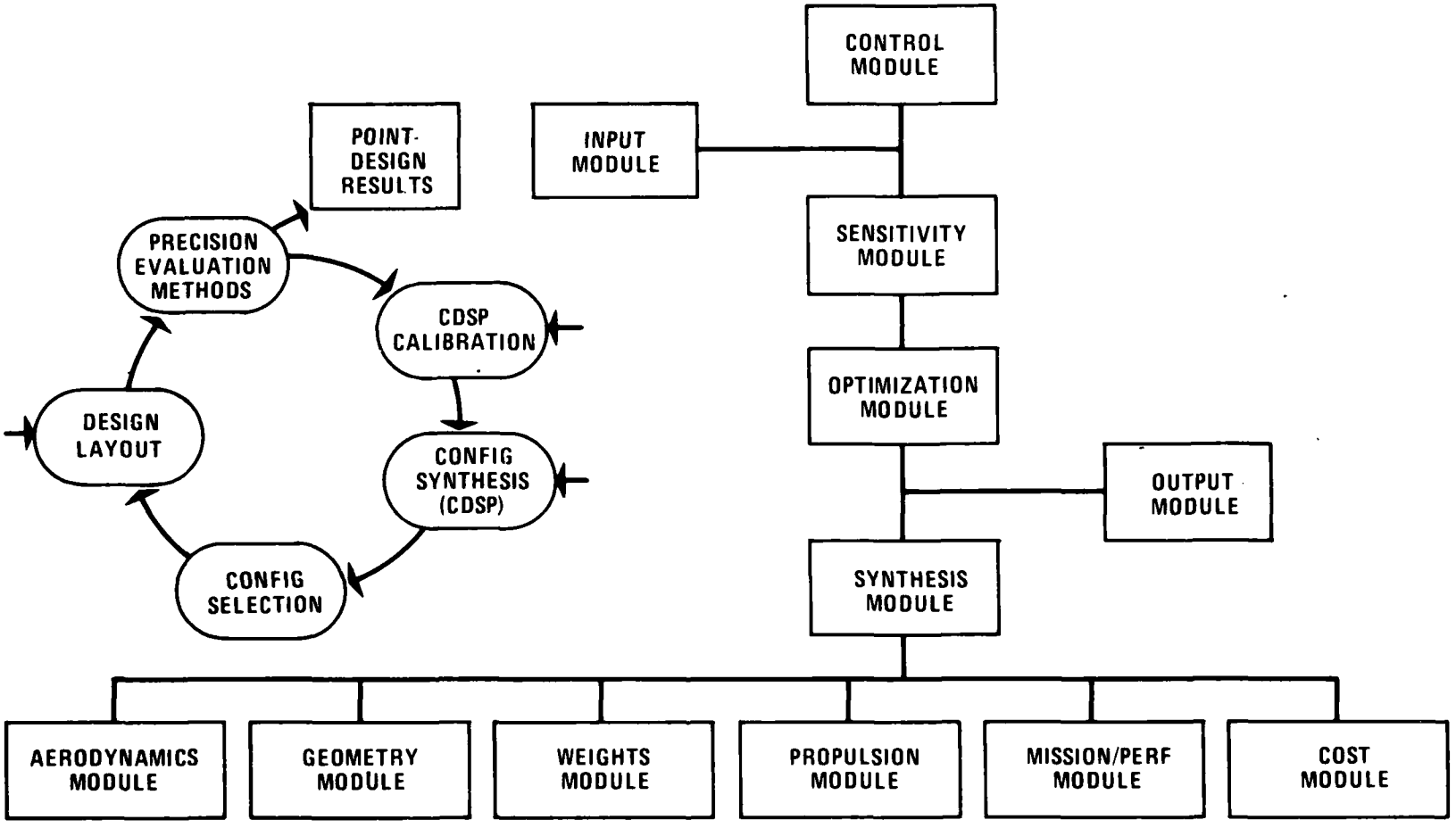
CL	CD	CDL	CDST
0.00000	.02191	0.00000	.00253
.10000	.02424	.00233	.00253
.20000	.03123	.00931	.00253
.30000	.04287	.02095	.00253
.40000	.05917	.03725	.00253
.50000	.08012	.05821	.00253
.60000	.10573	.08382	.00253
.70000	.13600	.11408	.00253
.80000	.17092	.14901	.00253
.90000	.21050	.18859	.00253

MINIMUM DRAG DATA CDM=CD0E+CDEX+CDWAVE (CDWAVE=CDWMG+CDWN+CDWF)

MACH	CDM	CD0E	CDEX	CDSTORE	CDWAVE	CDWMG	CDWN	CDWF	CLP	CD0E	K
.7000	.0106	.0106	0.0000	.0012	0.0000	0.0000	0.0000	0.0000	.6368	.0106	.1427
.8000	.0106	.0106	0.0000	.0012	0.0000	0.0000	0.0000	0.0000	.6495	.0106	.1427
.9000	.0106	.0106	0.0000	.0012	0.0000	0.0000	0.0000	0.0000	.6298	.0106	.1427
.9010	.0106	.0106	0.0000	.0012	0.0000	0.0000	0.0000	0.0000	.6788	.0106	.1427
.9020	.0106	.0106	0.0000	.0012	0.0000	0.0000	0.0000	0.0000	.6854	.0106	.1427
.9030	.0106	.0106	0.0000	.0012	0.0000	0.0000	0.0000	0.0000	.7078	.0106	.1427
.9040	.0106	.0106	0.0000	.0012	0.0000	0.0000	0.0000	0.0000	.7022	.0106	.1427
1.0000	.0164	.0106	0.0000	.0012	.0058	0.0000	0.0000	0.0000	.8022	.0164	.1427
1.1000	.0216	.0164	0.0000	.0025	.0112	.0086	0.0000	.0026	.8022	.0216	.2167
1.2000	.0219	.0164	0.0000	.0025	.0115	.0091	0.0000	.0026	.8022	.0219	.2328
1.3000	.0249	.0101	0.0000	.0025	.0149	.0095	.0027	.0026	.8022	.0249	.2569
1.4000	.0240	.0100	0.0000	.0025	.0141	.0085	.0030	.0026	.8022	.0240	.2758
1.5000	.0231	.0098	0.0000	.0025	.0133	.0074	.0033	.0026	.8022	.0231	.2907
1.6000	.0226	.0096	0.0000	.0025	.0129	.0069	.0035	.0026	.8022	.0226	.3117
1.7000	.0221	.0095	0.0000	.0024	.0126	.0063	.0037	.0026	.8022	.0221	.3335
1.8000	.0217	.0093	0.0000	.0024	.0123	.0059	.0039	.0026	.8022	.0217	.3559
1.9000	.0212	.0092	0.0000	.0024	.0121	.0055	.0040	.0026	.8022	.0212	.3790
2.0000	.0209	.0090	0.0000	.0024	.0119	.0051	.0042	.0026	.8022	.0209	.4030

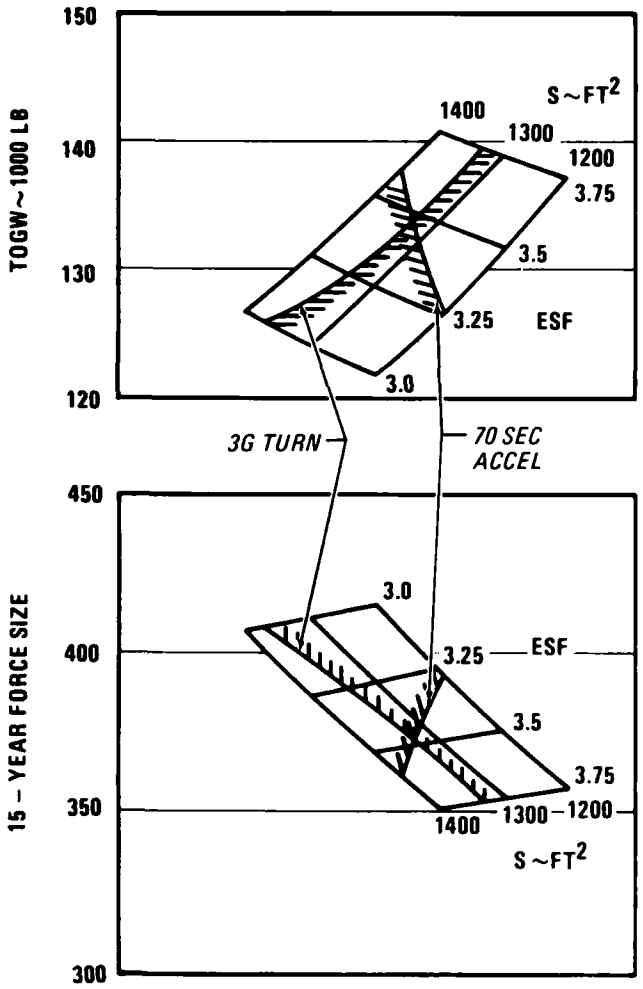
SB9428A

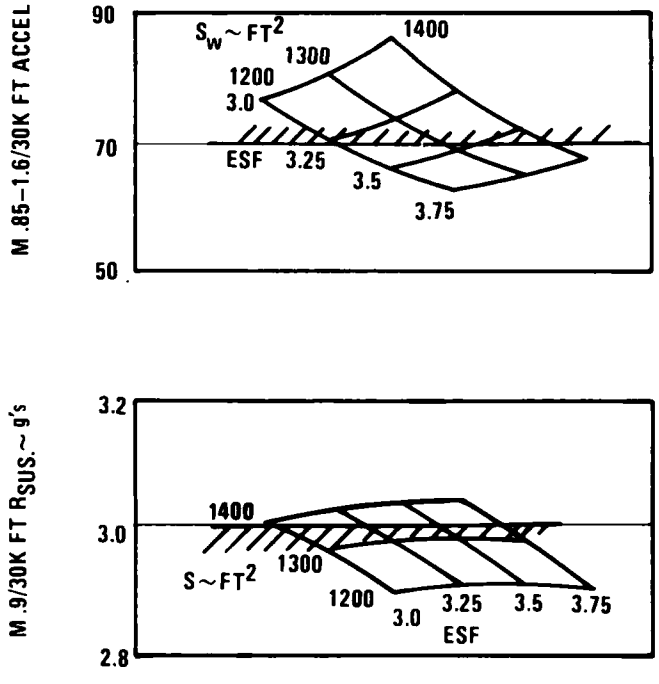
TYPICAL AIRCRAFT SYNTHESIS COMPUTATIONAL MODULES



TYPICAL CONFIGURATION SELECTION CARPET PLOTS – WING AREA/ENGINE–SCALE TRADES

M 3.0 DASH/LR MISSION
AR = 2.78
t/c = .036
Λ_{LE} = 35

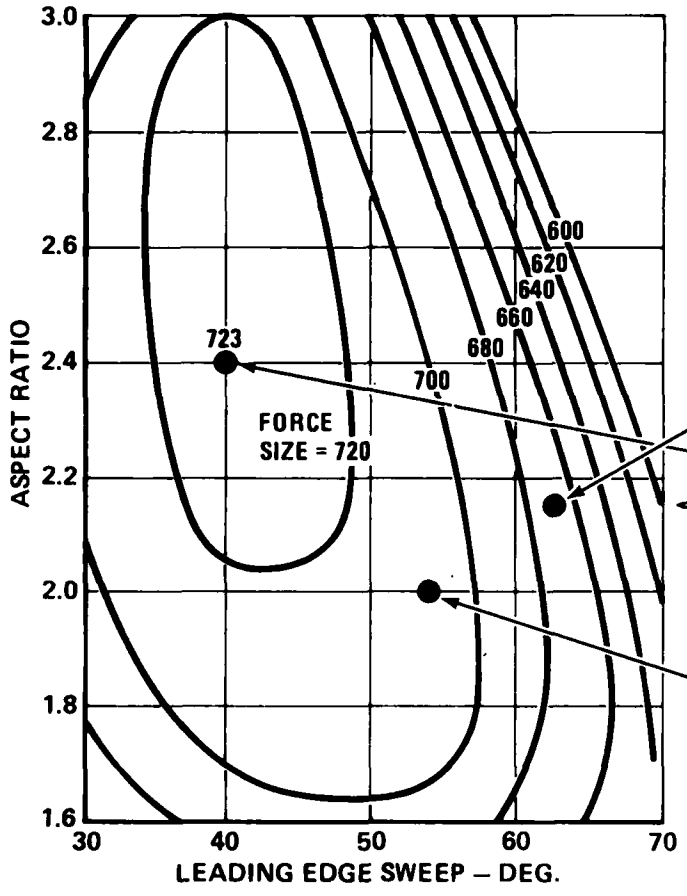


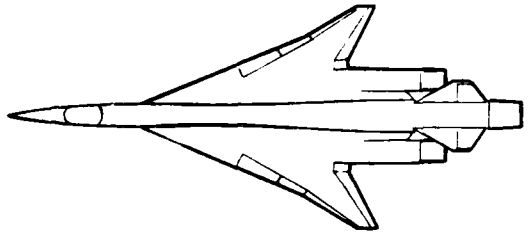


B27108

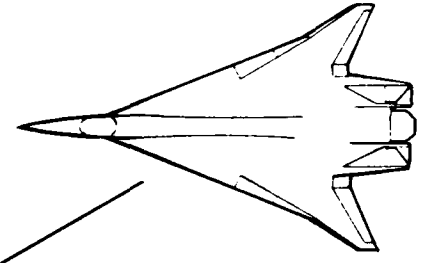
CONFIGURATION OPTIMIZATION – THE ANSWERS AREN'T SACRED

- ALL CONFIGURATIONS MEET MACH 2 LR MISSION, MANEUVER AND ACCEL. REQUIREMENTS
- ESF, S, t/c, l_f OPTIMIZED FOR EACH COMBINATION OF AR AND Λ_{LE}

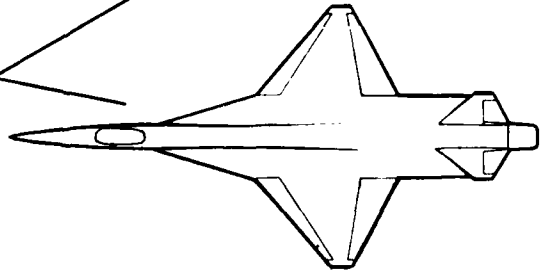




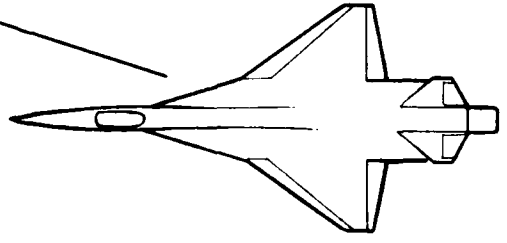
ORIGINAL CONFIGURATION 7-14 BASELINE



RESIZED TO MEET ATS REQUIREMENTS



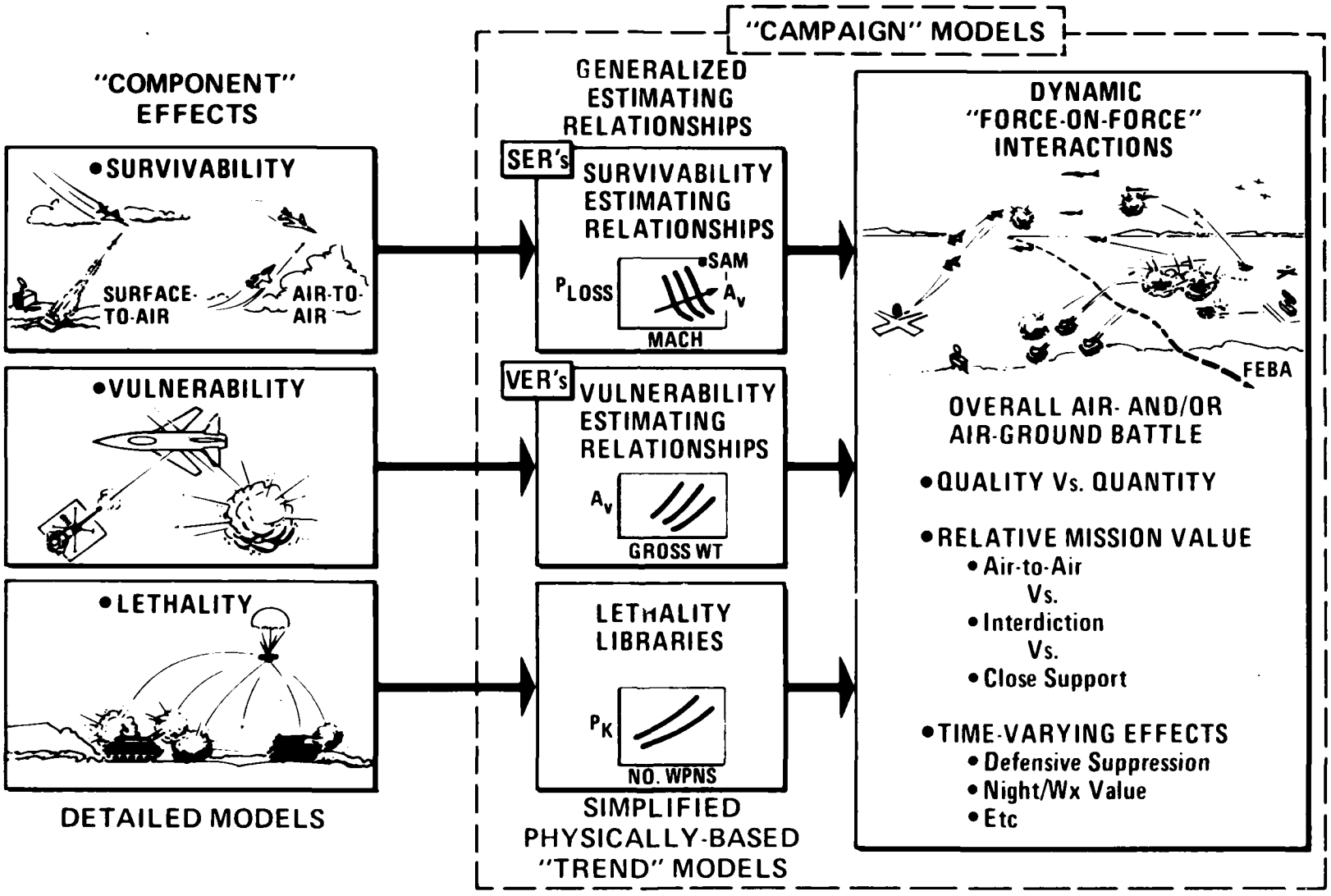
FULLY REOPTIMIZED PLANFORM



PARTIALLY REOPTIMIZED PLANFORM MAY BE MORE DESIRABLE FOR AREA – RULING AND TRIM CONSIDERATIONS

6B2026B

EFFECTIVENESS – BUILDING UP THE WHOLE PICTURE



B27129

OVERVIEW OF CAD EFFORTS AT GRUMMAN

Alfred Vachris
RAVES Project Manager
Grumman Aerospace
Bethpage, New York

OVERVIEW OF CAD EFFORTS AT GRUMMAN

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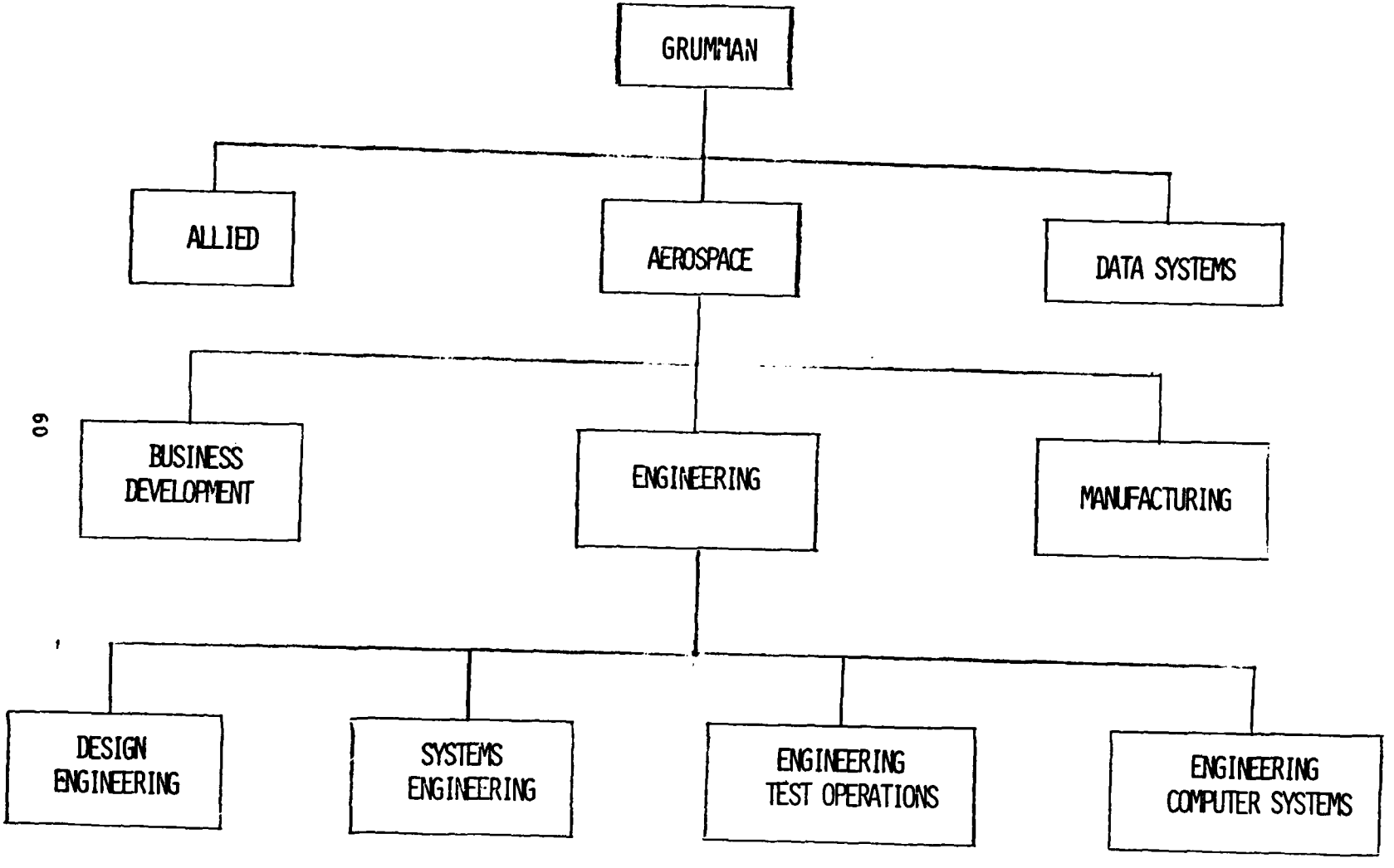
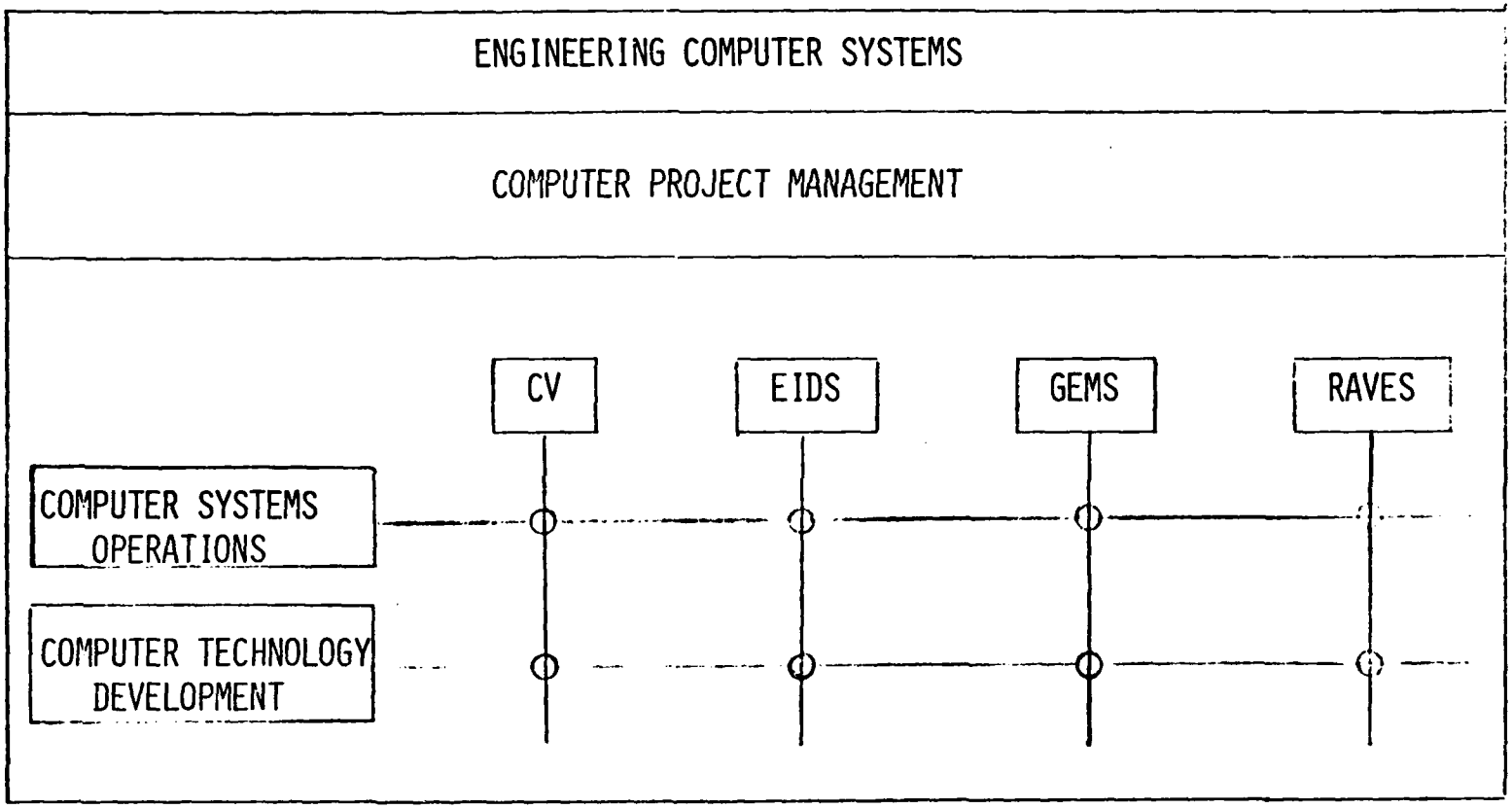
This paper presents an outline of the various CAD efforts that Grumman has evolved while building the Rapid Aerospace Vehicle Evaluation System (RAVES) and the Grumman Engineering Manufacturing System (GEMS), which have been developed during the last 10 years. Current efforts are to form an integration system, which will build a bridge from preliminary design to engineering to manufacturing. The system will outline the needs of vulnerability assessment and the broad-based requirement for a total 3D model of aircraft geometry, both internal and external. To accomplish the development of such a model as well as the ability to store and to use such a model will require a very sophisticated data base management capability. The paper concludes with a review of various modeling techniques.

COMPUTER AIDED DESIGN

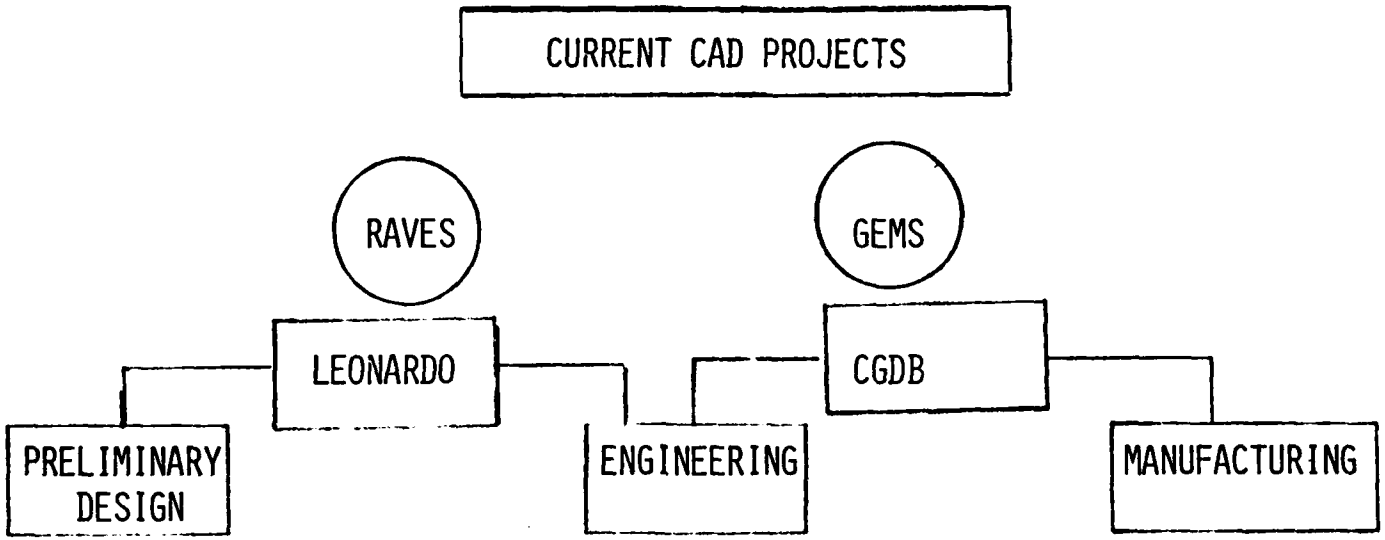
AT GRUMMAN

ALFRED VACHRIS
RAVES PROJECT
GRUMMAN AEROSPACE


GRUMMAN
ALLIED
AEROSPACE
DATA SYSTEMS
BUSINESS DEVELOPMENT
ENGINEERING
MANUFACTURING
DESIGN ENGINEERING
SYSTEMS ENGINEERING
ENGINEERING TEST OPERATIONS
ENGINEERING COMPUTER SYSTEMS

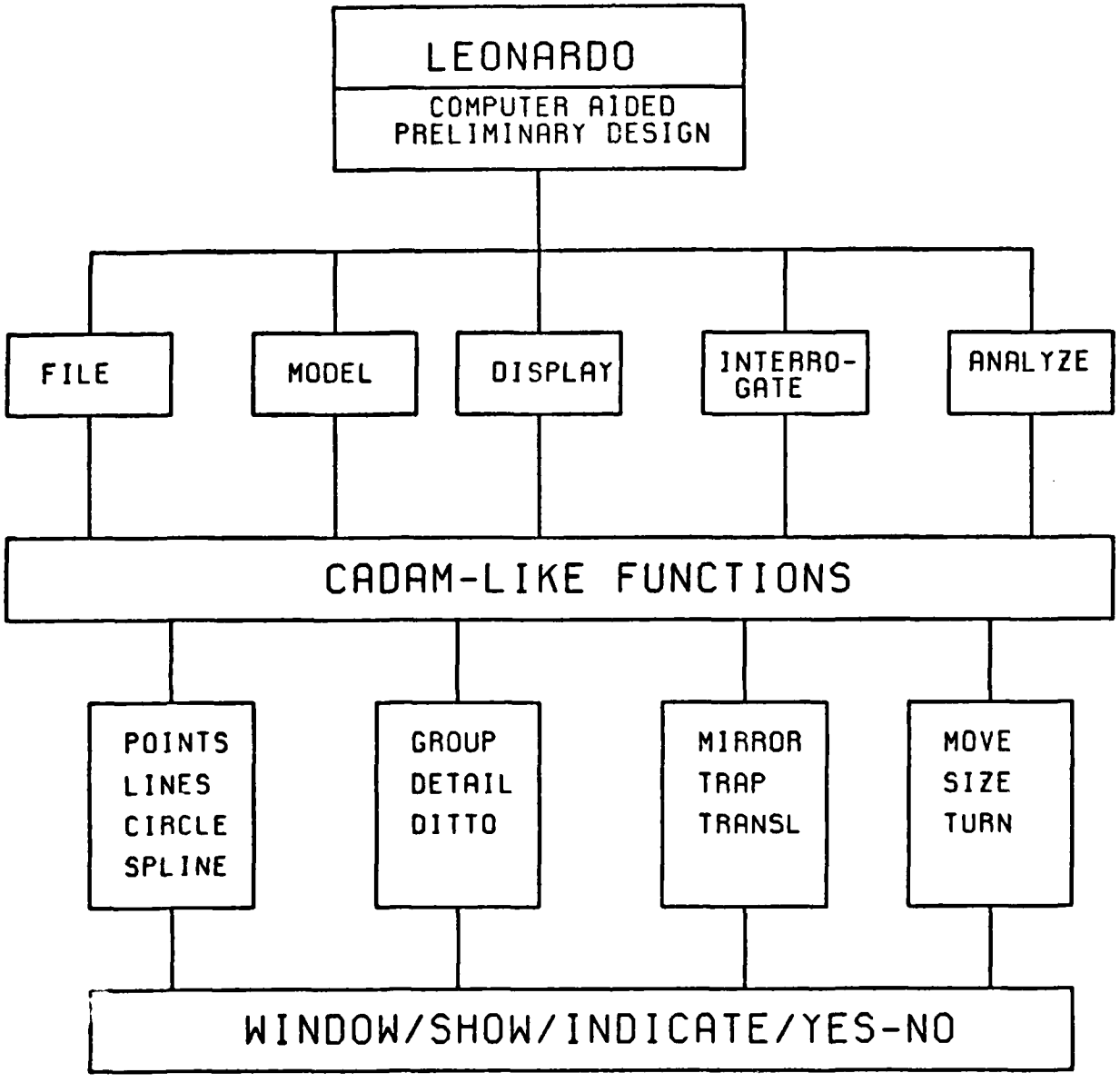


CV - COMPUTER VISION
EIDS - END ITEM DEFINITION SYSTEM
GEMS - GRUMMAN ENGINEERING MANUFACTURING SYSTEM
RAVES - RAPID AEROSPACE VEHICLE EVALUATION SYSTEM

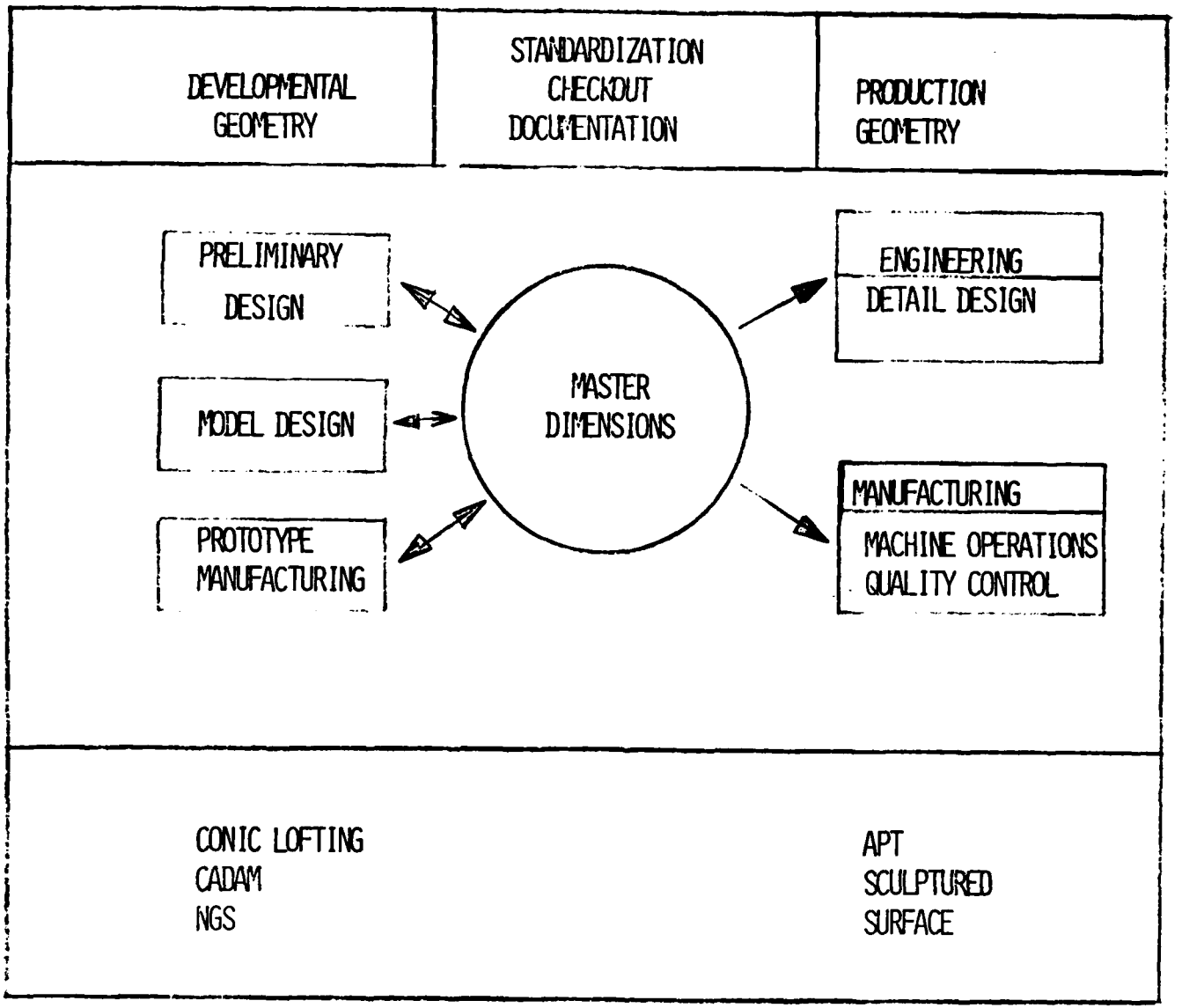


LEONARDO -- CONFIGURATION DESIGN SYSTEM

CGDB -- CORPORATE GEOMETRY DATA BANK

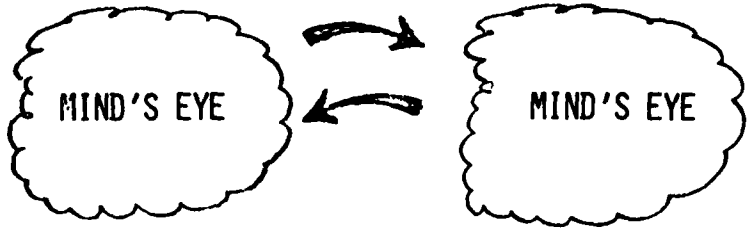

LEONARDO
COMPUTER AIDED PRELIMINARY DESIGN
FILE
MODEL
DISPLAY
INTERRO-GATE
ANALYZE
CADAM-LIKE FUNCTIONS
POINTS
LINES
CIRCLE
SPLINE
GROUP
DETAIL
DITTO
MIRROR
TRAP
TRANSL
MOVE
SIZE
TURN
WINDOW/SHOW/INDICATE/YES-NO

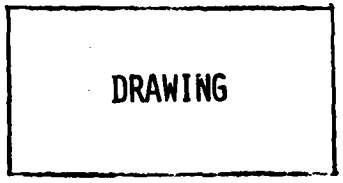
CORPORATE GEOMETRY DATA BANK



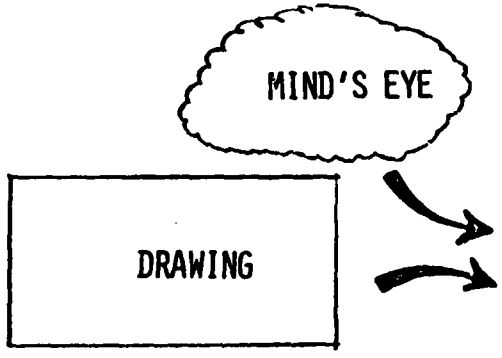
CAD ?

COMPUTER AIDED DRAWING ? COMPUTER AIDED DESIGN ? COMPUTER AIDED ENGINEERING ?

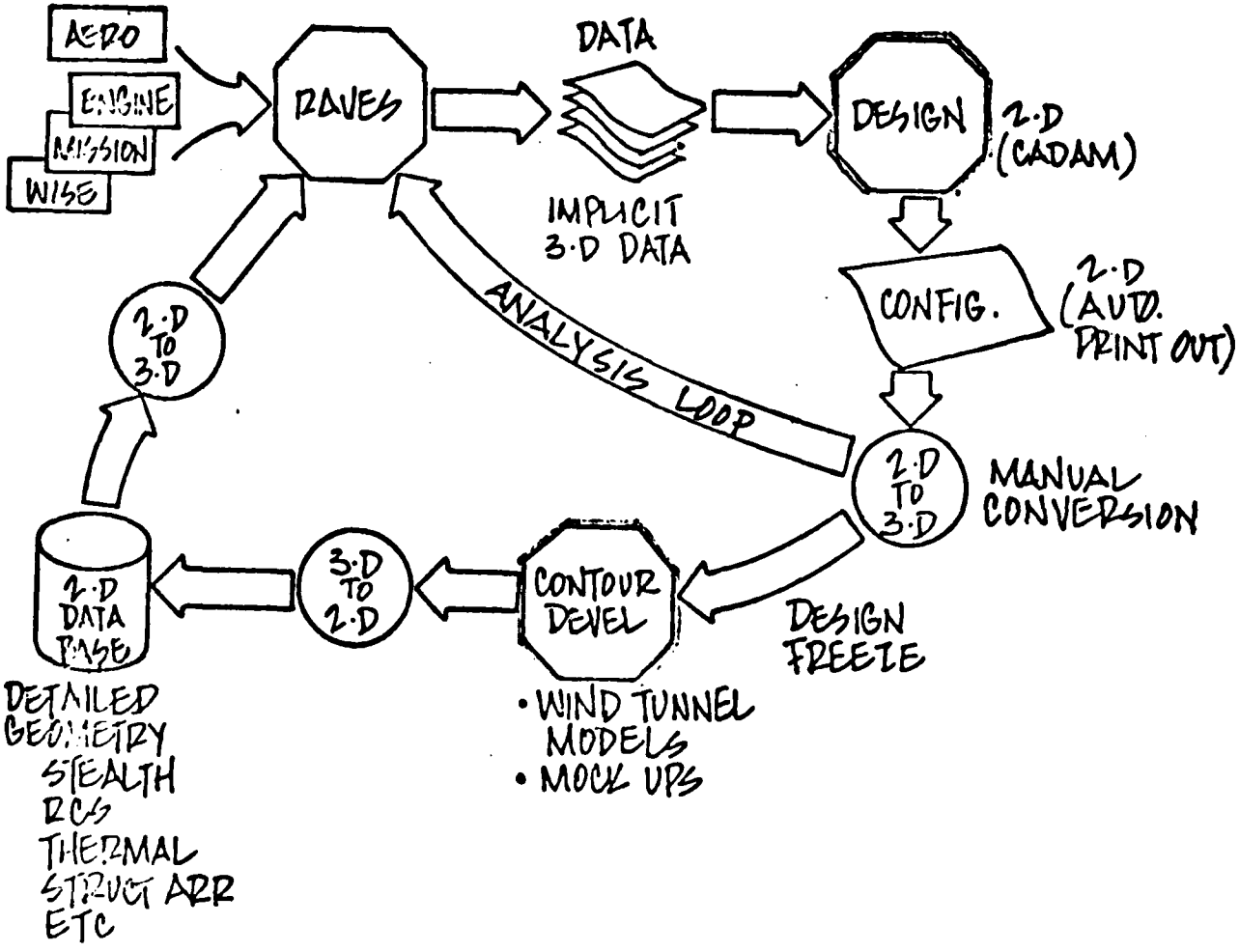




DRAWING IMPLICITLY DEFINES DESIGN BASED ON COMMON INTERPRETATION



DESIGN EXPLICITLY DEFINED BY COMPUTER MODEL USED WITHOUT INTERPRETATION


AERO
ENGINE
MISSION
WISE
RAVES
DATA
IMPLICIT
3·D DATA
DESIGN
2·D
(CADAM)
CONFIG.
2·D
(AUTO.
PRINT OUT)
ANALYSIS LOOP
2·D
TO
3·D
MANUAL
CONVERSION
DESIGN
FREEZE
CONTOUR
DEVEL
• WIND TUNNEL
MODELS
• MOCK UPS
3·D
TO
2·D
2·D
DATA
BASE
DETAILED
GEOMETRY
STEALTH
RCS
THERMAL
STRUCT ARR
ETC

FUTURE CAD PROJECT

RAVES ⟷ GEMS

INTEGRATED GEOMETRY SYSTEM

PRELIMINARY DESIGN	ENGINEERING	MANUFACTURING

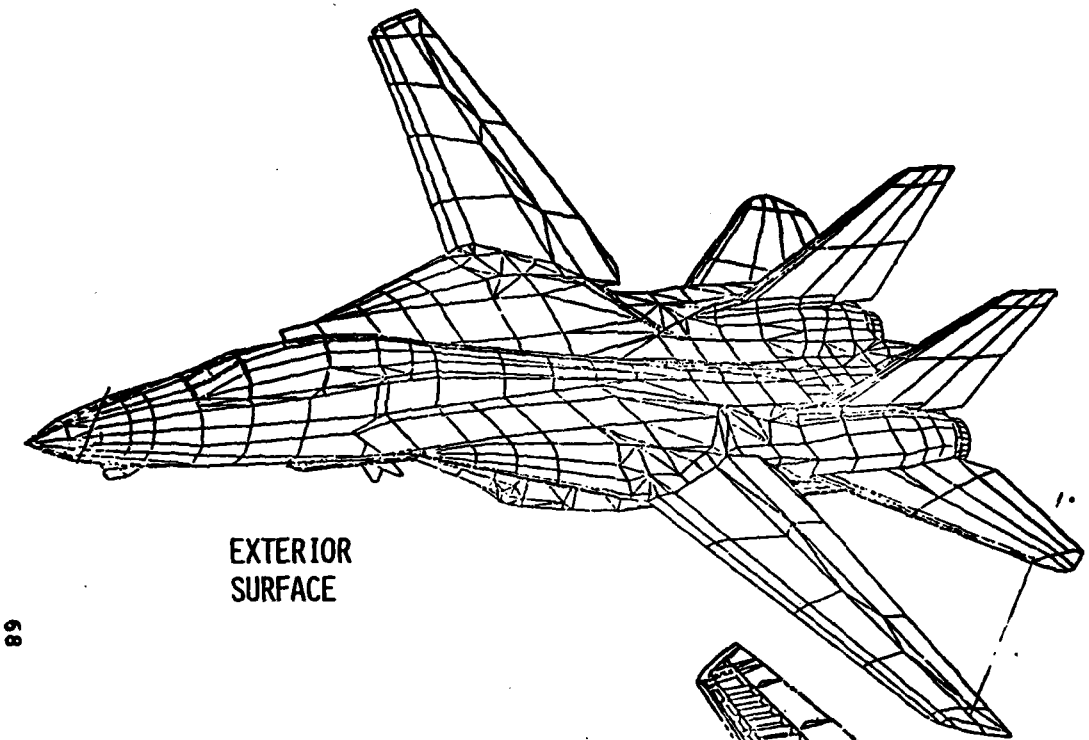
STANDARD FUNCTIONS

* CREATE
* STORE
* RECALL
* INTERROGATE
* REPORT

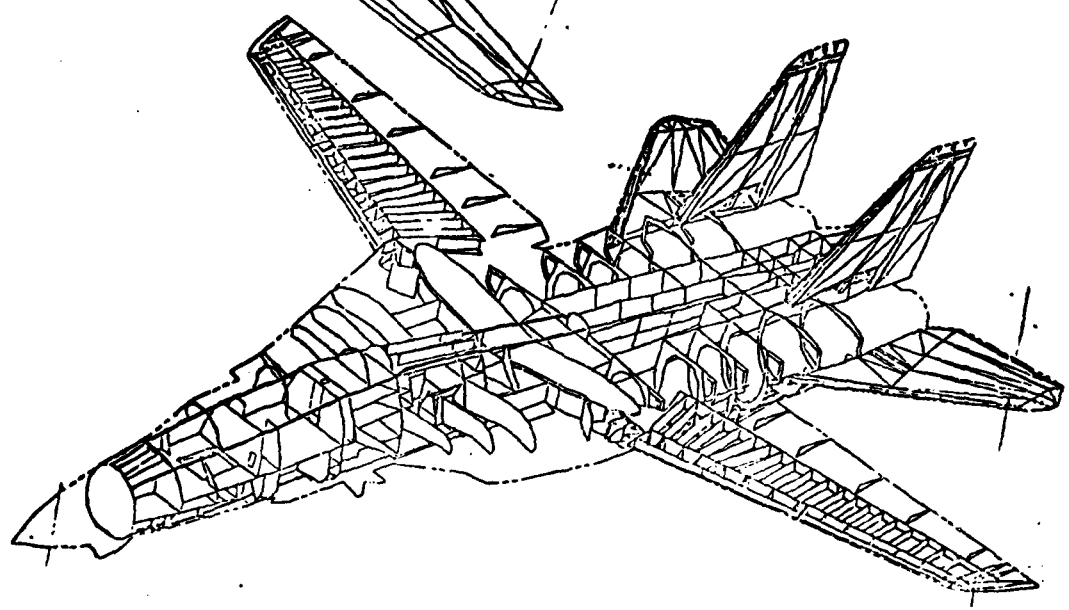
INTELLIGENT FUNCTIONS

* COLLECT
* ORGANIZE
* STRUCTURE

→ GENERATE ADDITIONAL GEOMETRY INFORMATION

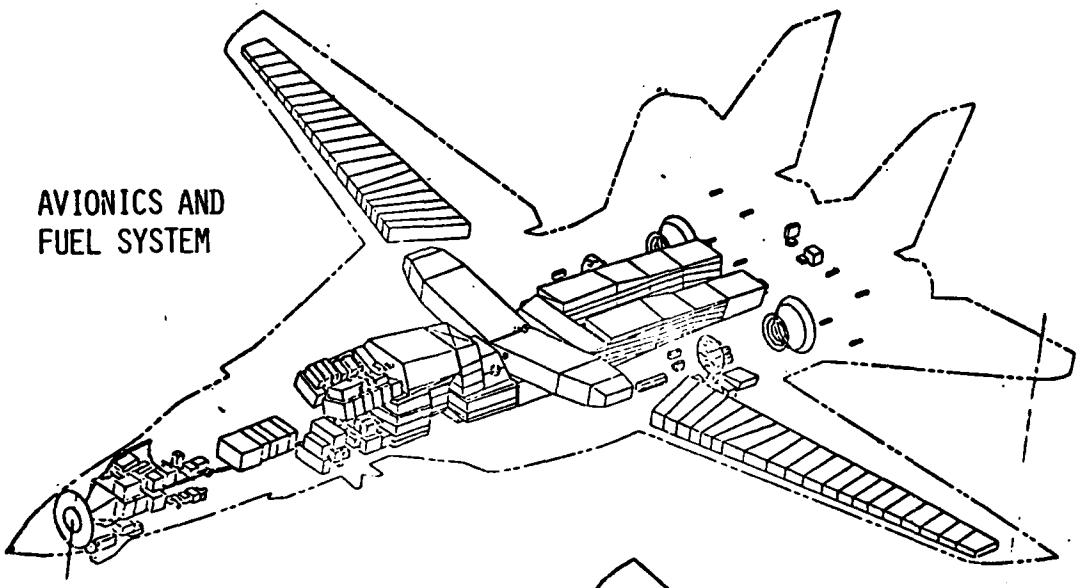


EXTERIOR
SURFACE

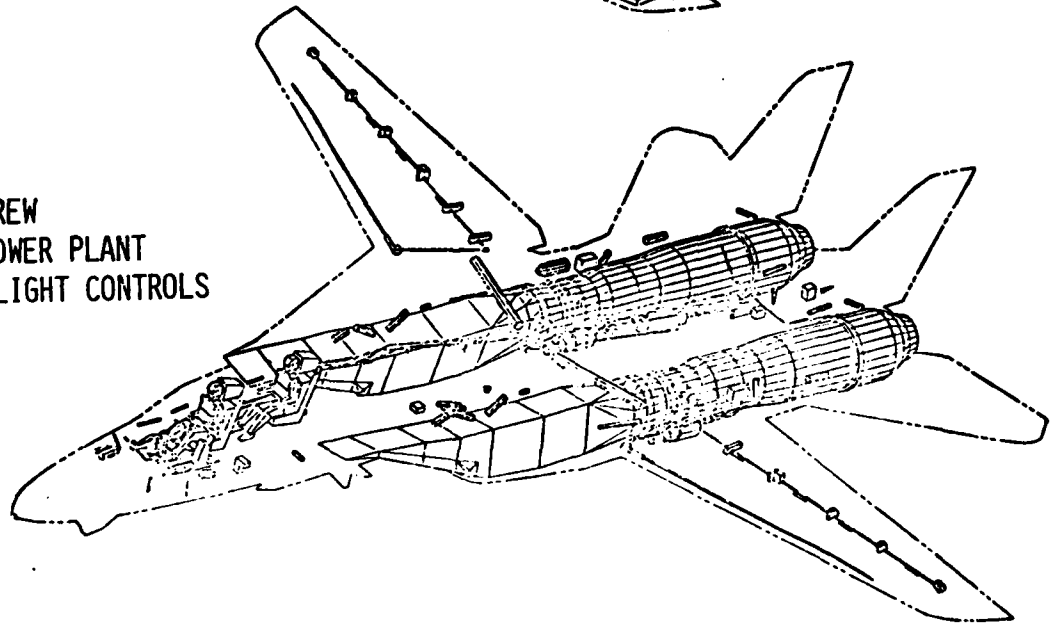


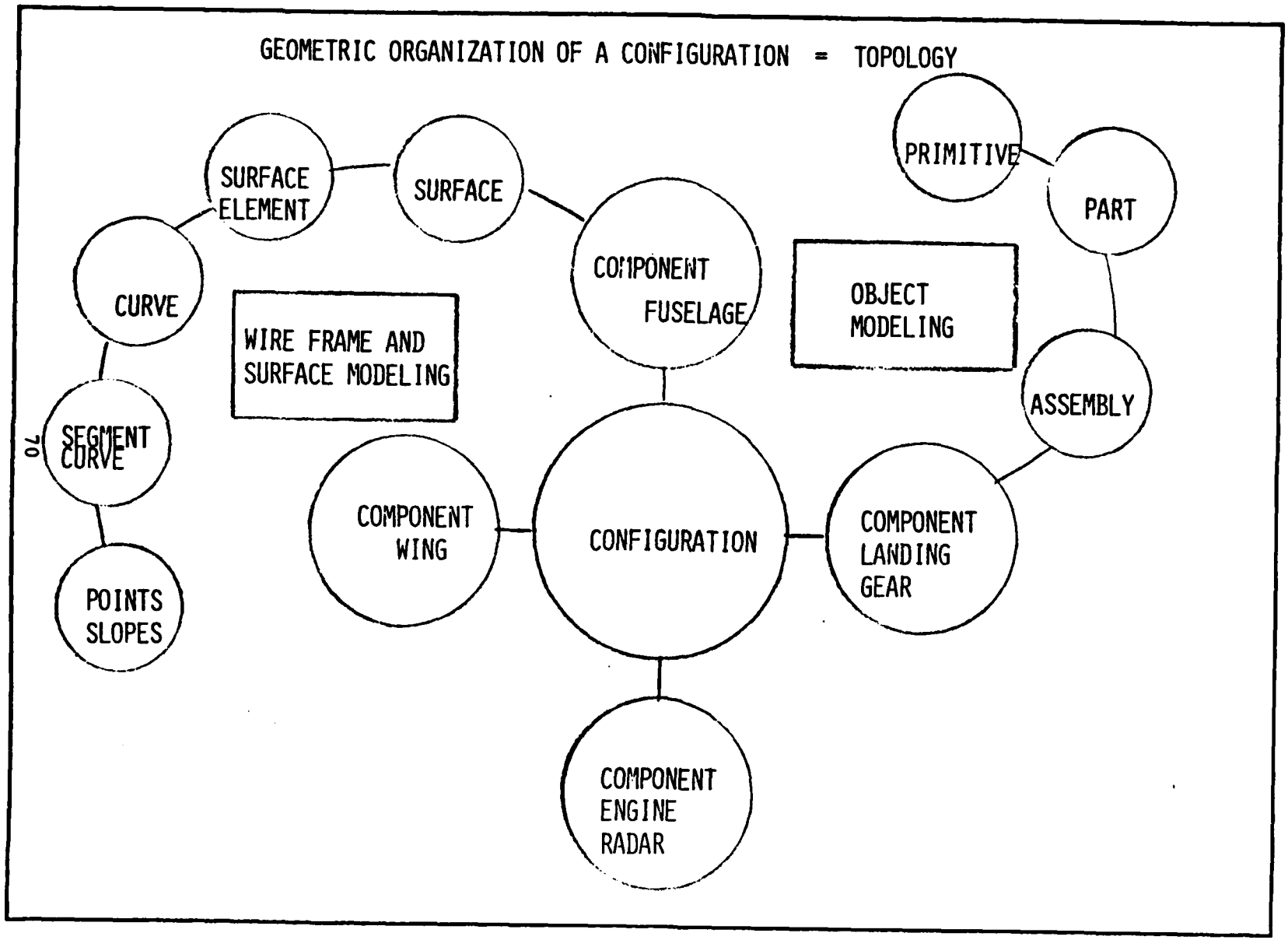
STRUCTURAL
COMPONENTS

AVIONICS AND
FUEL SYSTEM

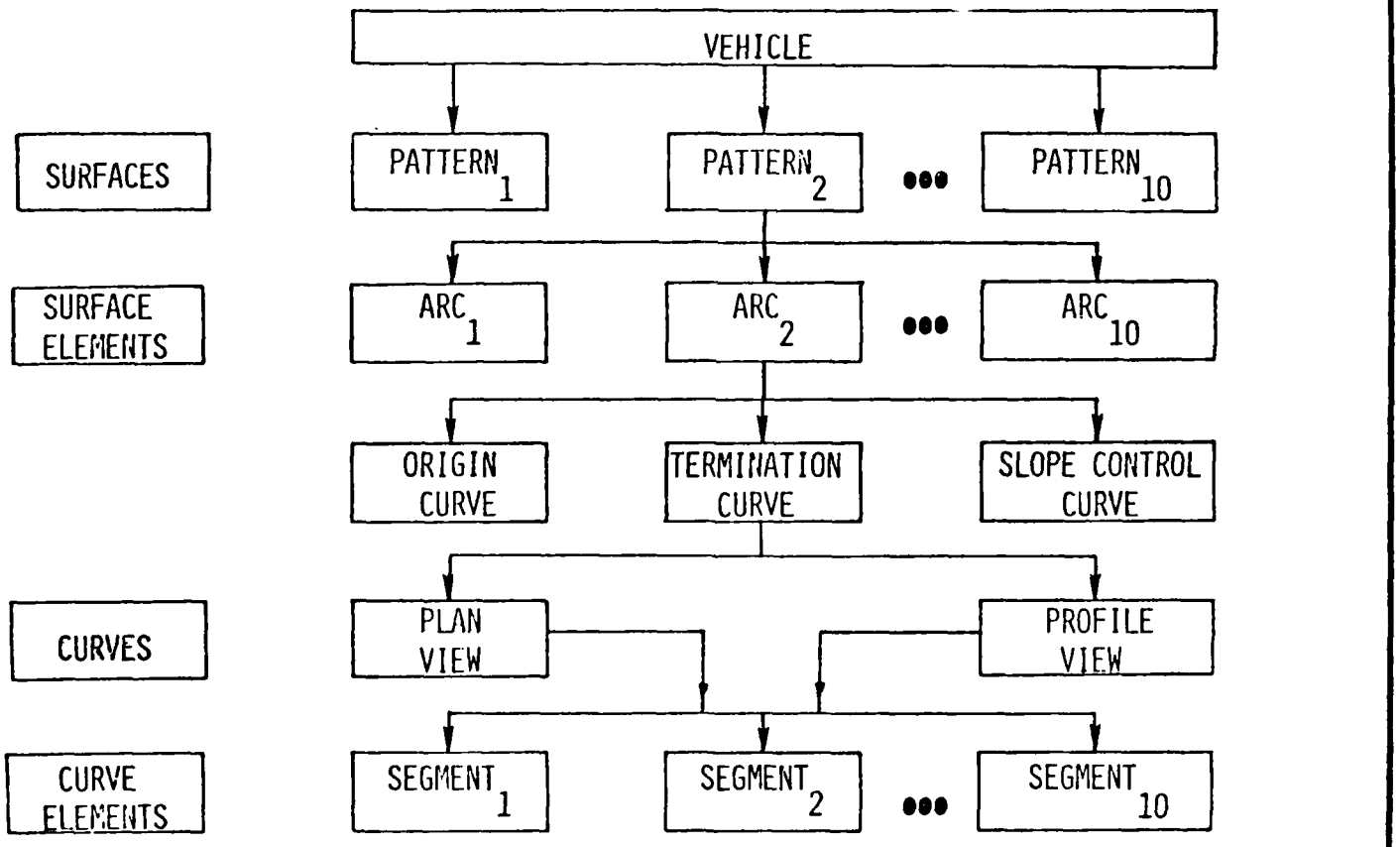


CREW
POWER PLANT
FLIGHT CONTROLS




GEOMETRIC ORGANIZATION OF A CONFIGURATION = TOPOLOGY
SURFACE ELEMENT
SURFACE
PRIMITIVE
PART
CURVE
COMPONENT FUSELAGE
OBJECT MODELING
WIRE FRAME AND SURFACE MODELING
ASSEMBLY
SEGMENT CURVE
COMPONENT WING
CONFIGURATION
COMPONENT LANDING GEAR
POINTS SLOPES
COMPONENT ENGINE RADAR

DATA STRUCTURE



GRUMMAN

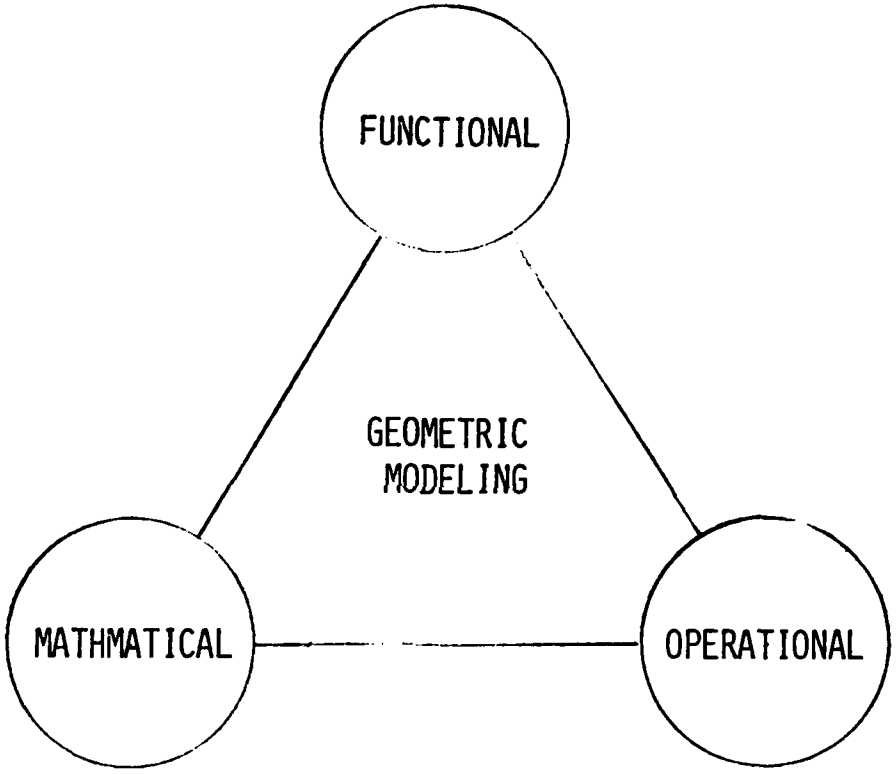
TOPOLOGY

* COLLECT ELEMENTS TO FORM NEW ELEMENTS
  DEVELOP AND RECORD CONNECTIVITY
  BUILD A CURVE FROM CURVE SEGMENTS

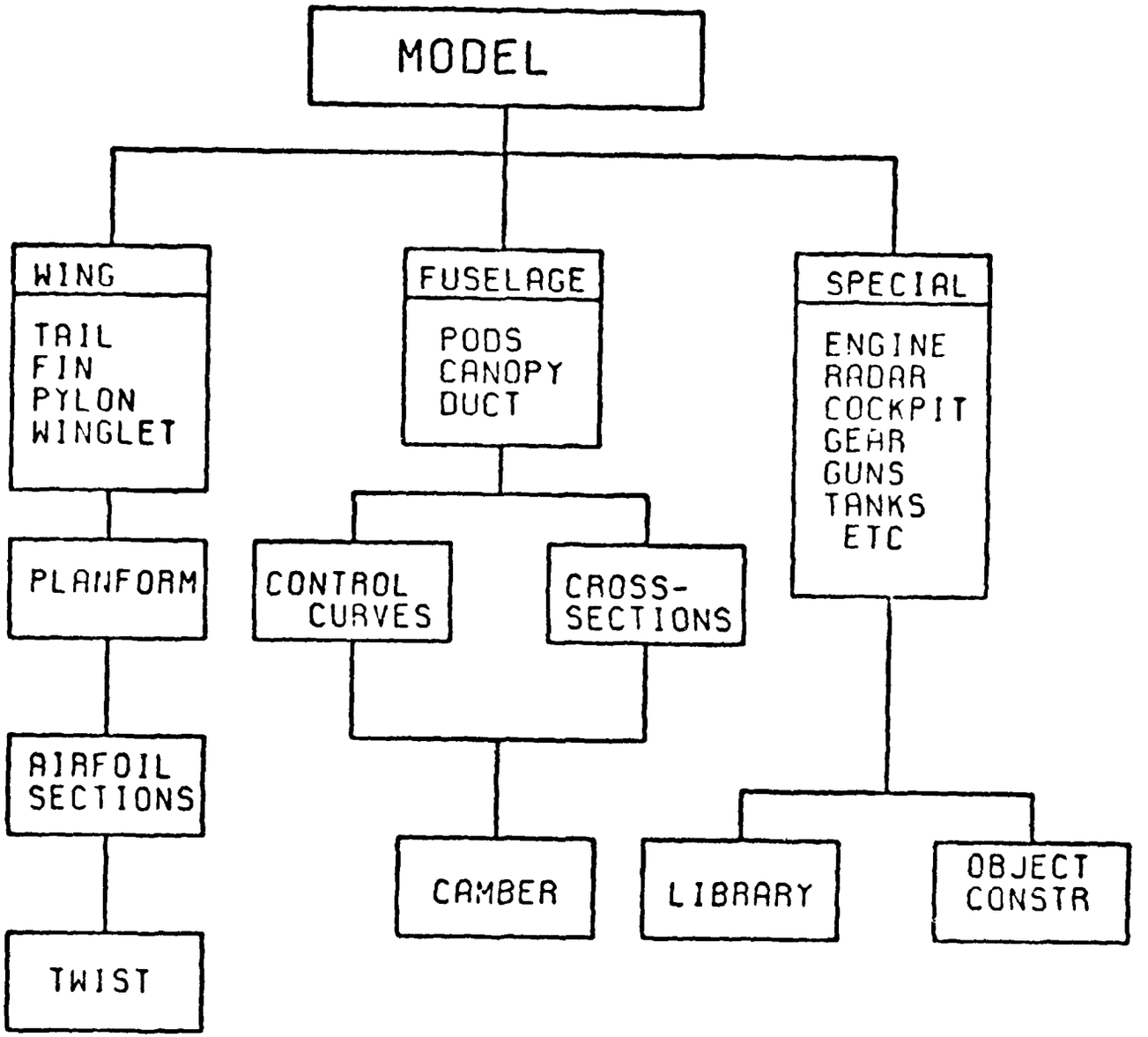
* COLLECT ELEMENTS INTO FUNCTIONAL GROUPS
  DEVELOP AND RECORD PARENT - CHILD RELATIONSHIPS
  FORM A SURFACE FROM BOUNDARY CURVES

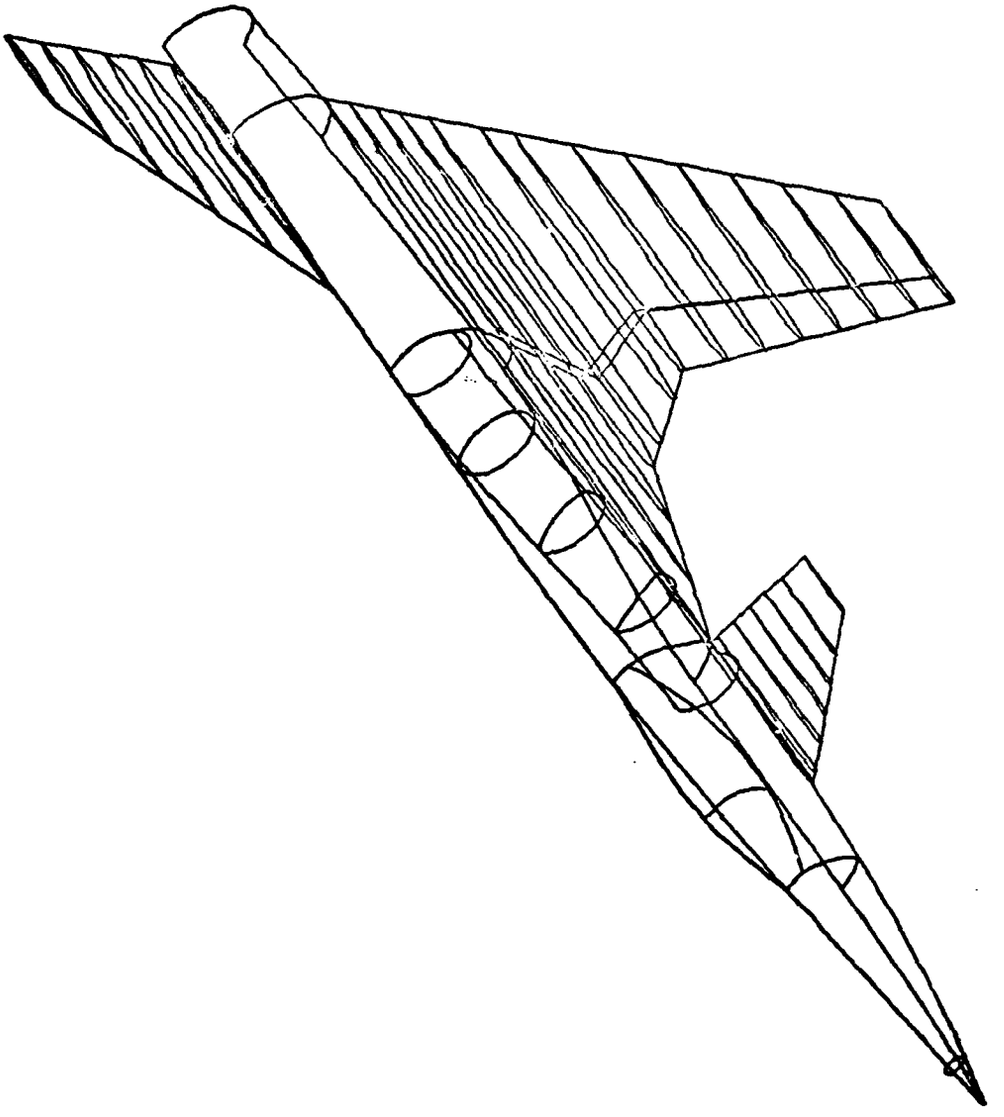
* DEFINE PARAMETRIC GEOMETRY
  CHANGE IN GEOMETRY IS EQUIVALENT TO A CHANGE
  IN PARAMETERS

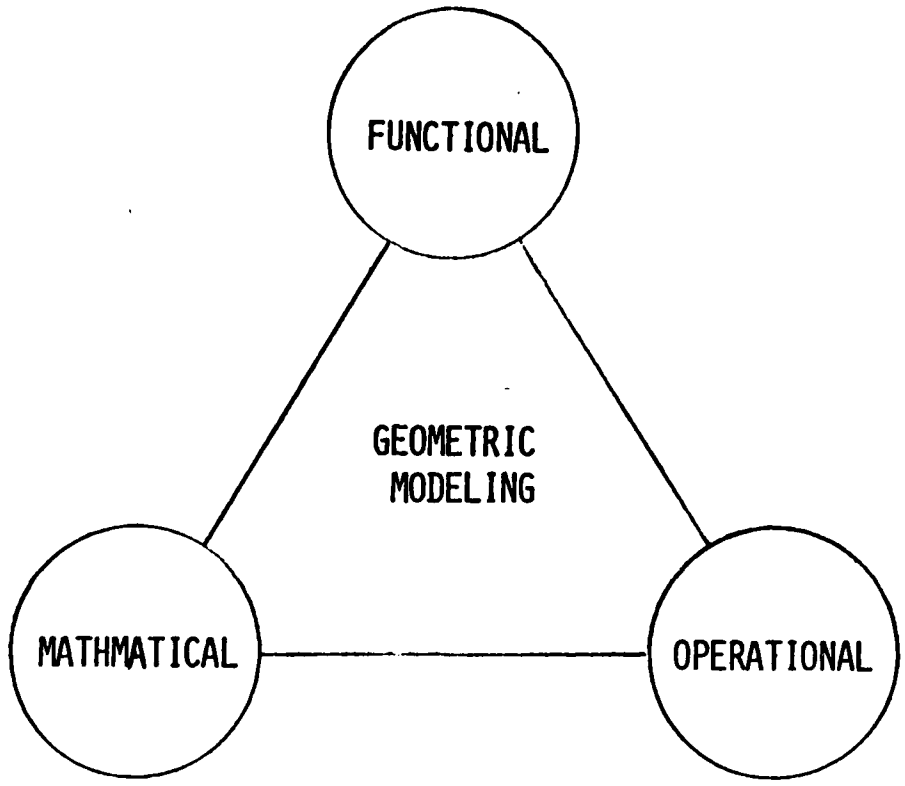
* RELATE DATA TO GEOMETRIC ELEMENTS
  DEFINE ATTRIBUTES



FUNCTIONAL - FUSELAGE/WING/SPECIAL COMPONENTS
MATHEMATICAL - WIRE FRAME/SURFACE/OBJECT
OPERATIONAL - MOLD/BLEND/ASSEMBLE/SUB-DIVIDE


MODEL
WING
TAIL
FIN
PYLON
WINGLET
FUSELAGE
PODS
CANOPY
DUCT
SPECIAL
ENGINE
RADAR
COCKPIT
GEAR
GUNS
TANKS
ETC
PLANFORM
CONTROL CURVES
CROSS-SECTIONS
AIRFOIL SECTIONS
CAMBER
LIBRARY
OBJECT CONSTR
TWIST

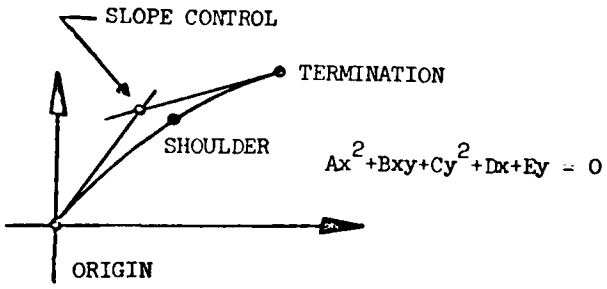




FUNCTIONAL - FUSELAGE/WING/SPECIAL COMPONENTS
MATHEMATICAL - WIRE FRAME/SURFACE/OBJECT
OPERATIONAL - MOLD/BLEND/ASSEMBLE/SUB-DIVIDE

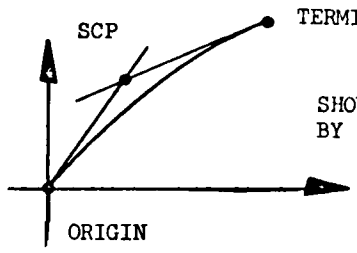
CURVE ELEMENT DEFINITION

STANDARD LOFTING CONIC



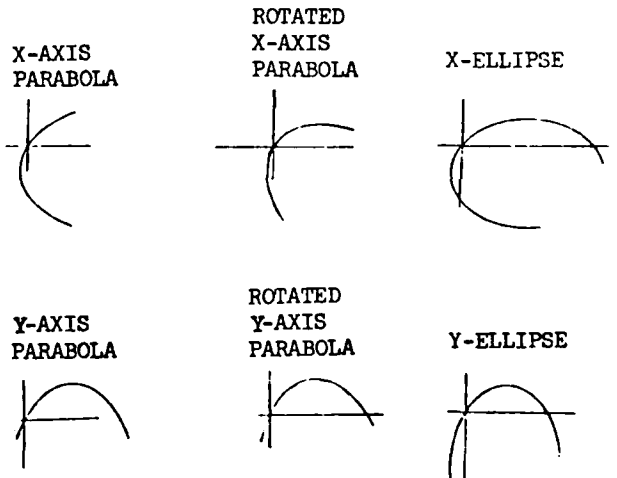
$Ax^2+Bxy+Cy^2+Dx+Ey = 0$

QUICK CURVE SEGMENT



SHOULDER POINT IS REPLACED BY SHAPE SPECIFICATION

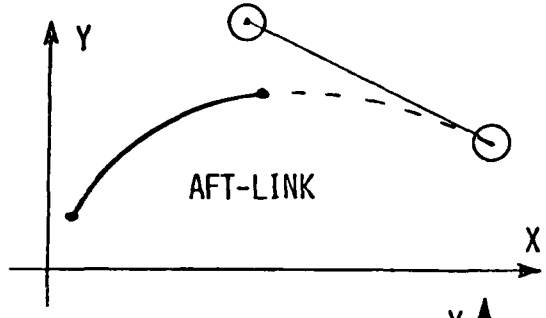
SHAPE	KEYWORD	EQUATION
Line	LINE	$Ax+By = 0$
x-Parabola	XPAR	$Ax+By+y^2 = 0$
y-Parabola	YPAR	$Ax+By+x^2 = 0$
Rotated x-Parabola	RXPA	$Ax+By+Cxy+y^2 = 0$
Rotated y-Parabola	RYPA	$Ax+By+Cxy+x^2 = 0$
x-Ellipse	ELLX	$Ax+By+Cx^2+y^2 = 0$
y-Ellipse	ELLY	$Ax+By+Cy^2+x^2 = 0$
Cubic	CUBI(C)	$Ax+By+Cx^2+x^3 = 0$

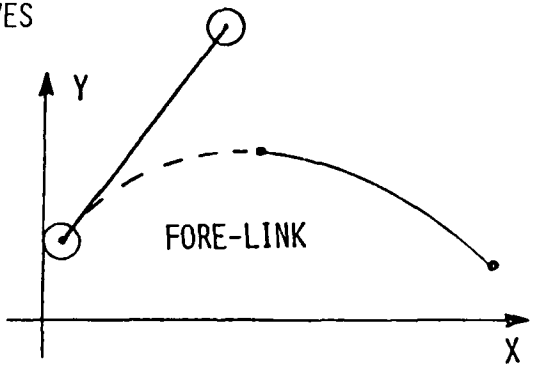


GRUMMAN

BLENDING CONTROL FOR CURVE ELEMENTS

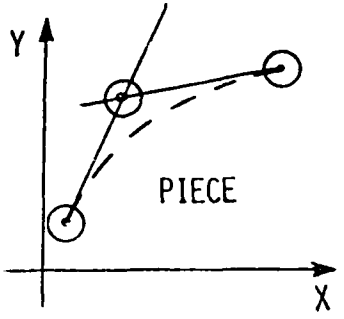
CURVE ELEMENTS ARE BLENDED
TOGETHER TO BUILD UP CURVES





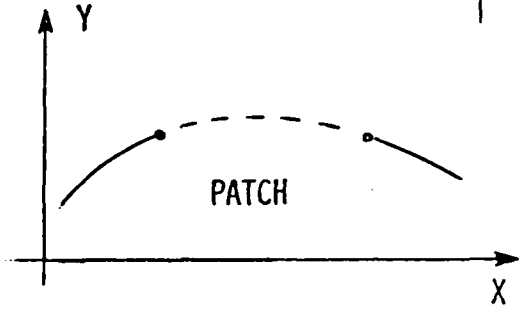
KNOWN POINT •

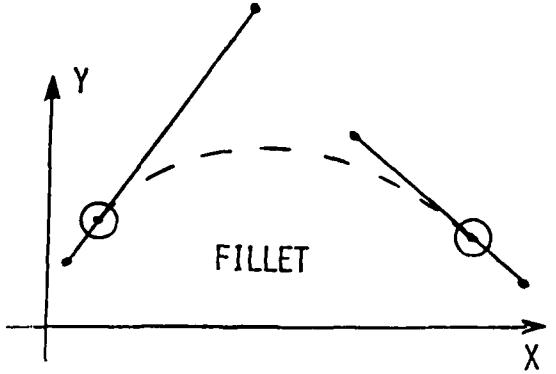
INPUT POINT ⊙



KNOWN SEGMENT ——————

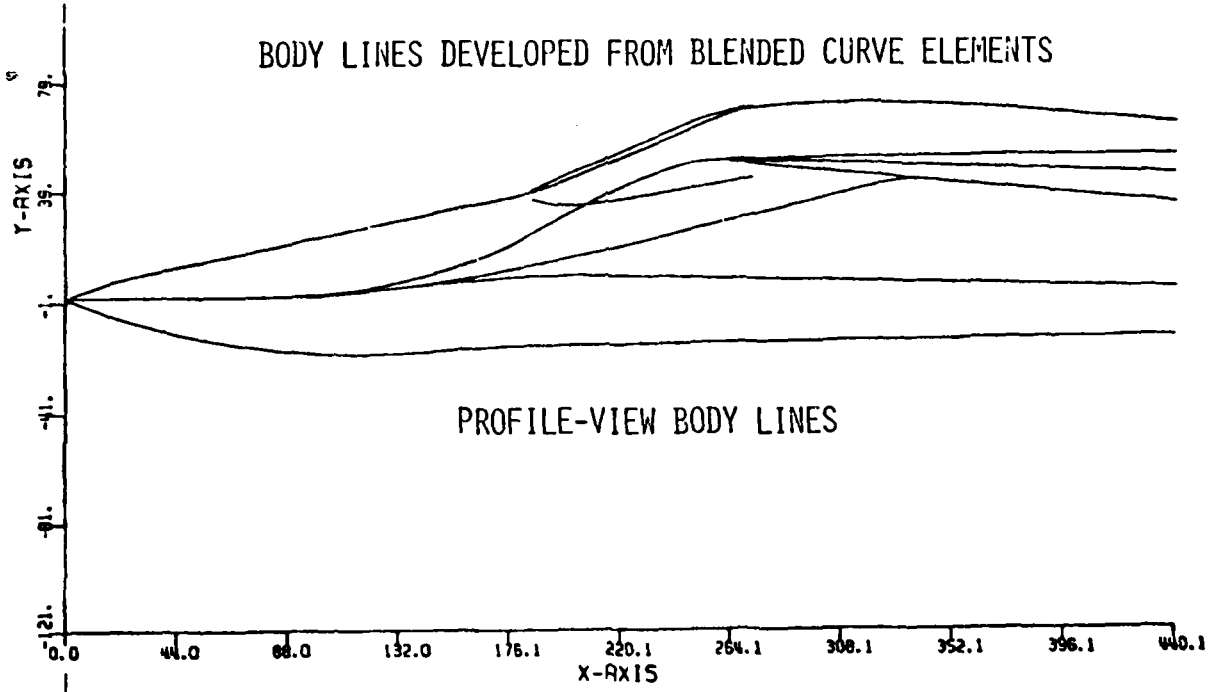
INPUT SEGMENT – – – –



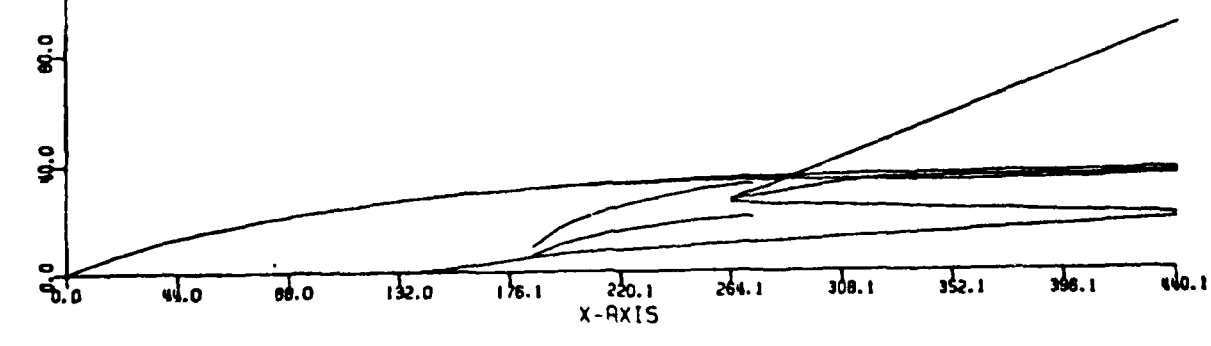


GRUMMAN

BODY LINES DEVELOPED FROM BLENDED CURVE ELEMENTS



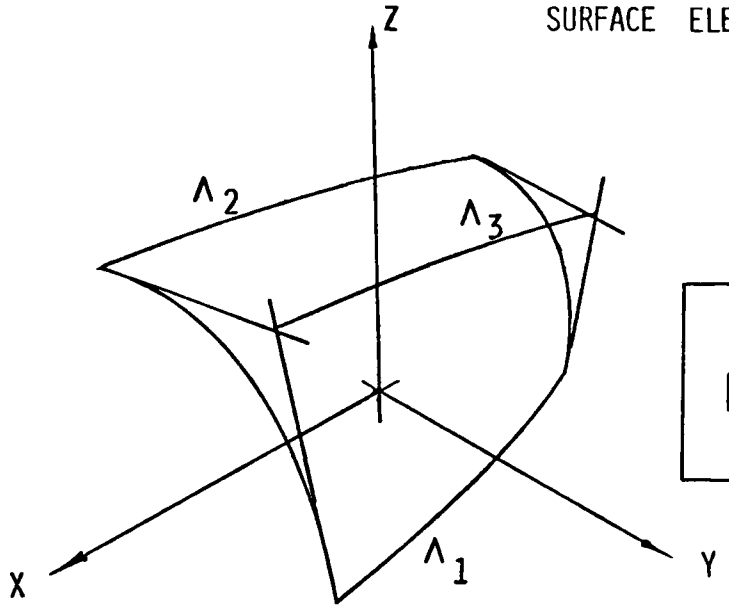
PROFILE-VIEW BODY LINES



PLAN-VIEW BODY LINES

GRUMMAN

SURFACE ELEMENT



Λ_1 - ORIGIN CURVE
Λ_2 - TERMINATION CURVE
Λ_3 - SLOPE CONTROL CURVE

TYPICAL SHAPE → GROWING ELLIPSE

$$\frac{[Y(X)-Y_o(X)]^2}{A^2(X)} + \frac{[Z(X)-Z_o(X)]^2}{B^2(X)} = 1$$

NOTE THAT QUICK USES BOTH CARTESIAN AND POLAR COORDINATES

POLAR FORM $Q(R, R_o, \theta, \theta_o, A^2, B^2) = 0$

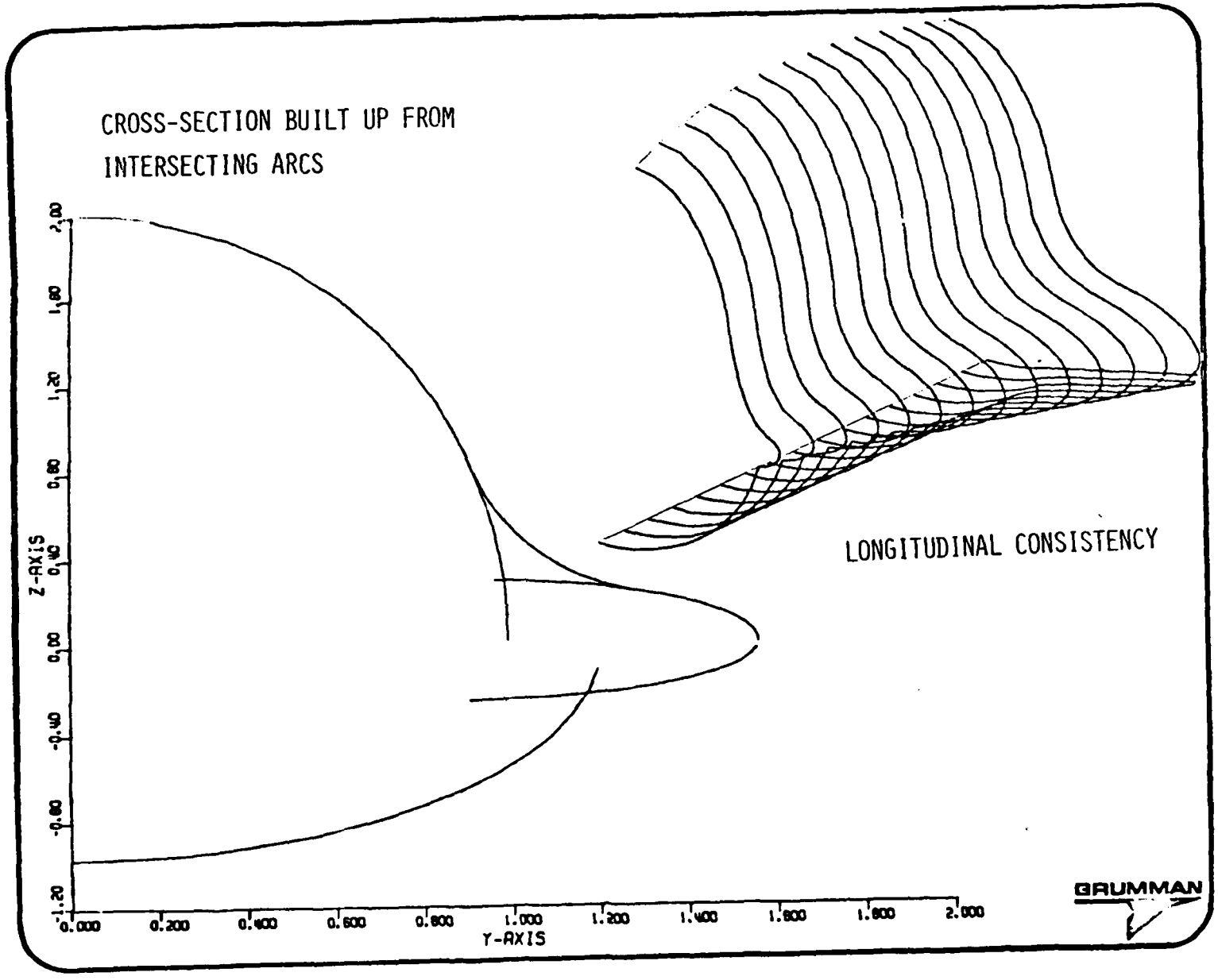
$$B^2 (R \cos\theta - R_o \cos\theta_o)^2 + A^2 (R \sin\theta - R_o \sin\theta_o)^2 - A^2 B^2 = 0$$

WHERE $R_o = R_o(X)$; $\theta_o = \theta_o(X)$; $A^2 = A^2(X)$; $B^2 = B^2(X)$

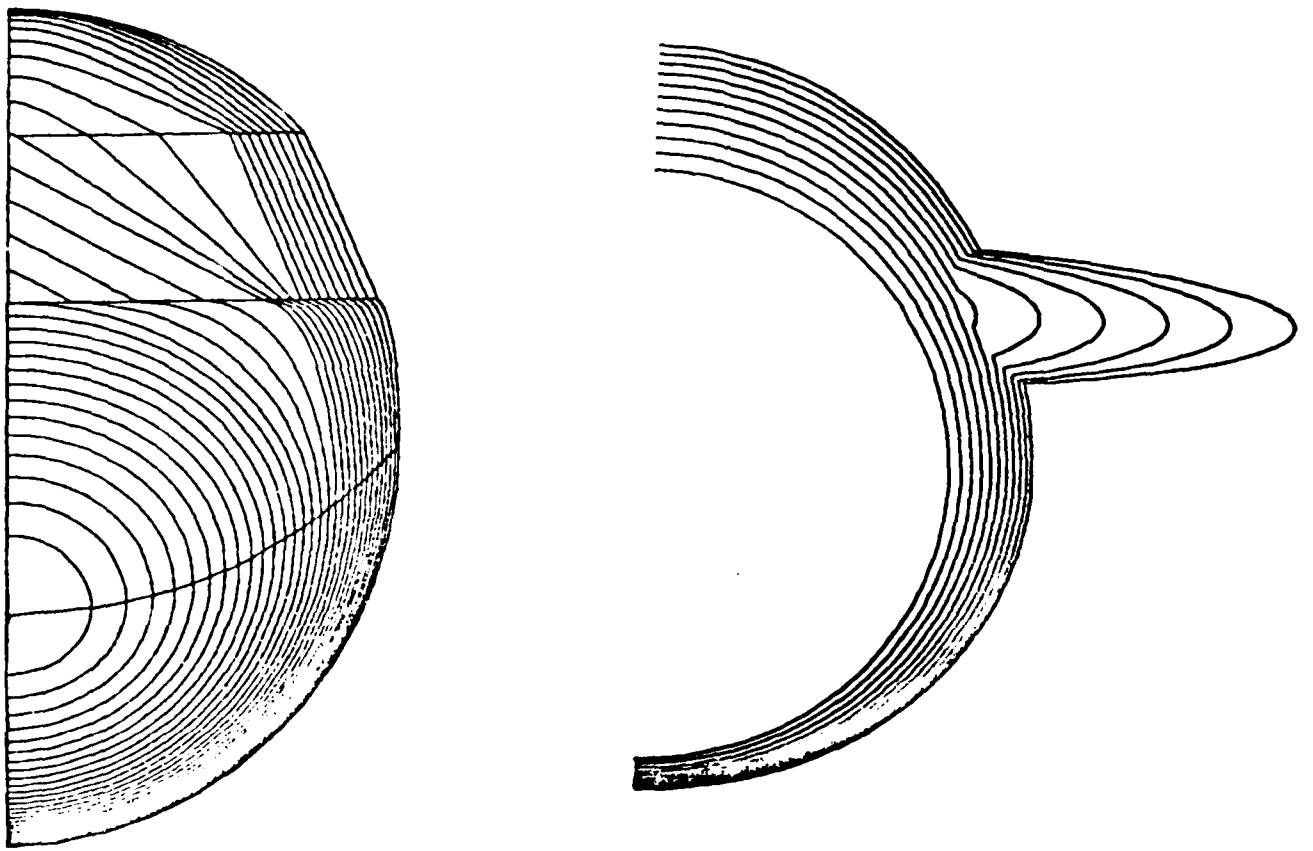
Q IS DIFFERENTIABLE PRODUCING

$$\frac{\partial R}{\partial X}, \frac{\partial R}{\partial \theta}, \frac{\partial^2 R}{\partial X^2}, \frac{\partial^2 R}{\partial X \partial \theta}, \frac{\partial^2 R}{\partial \theta^2}$$

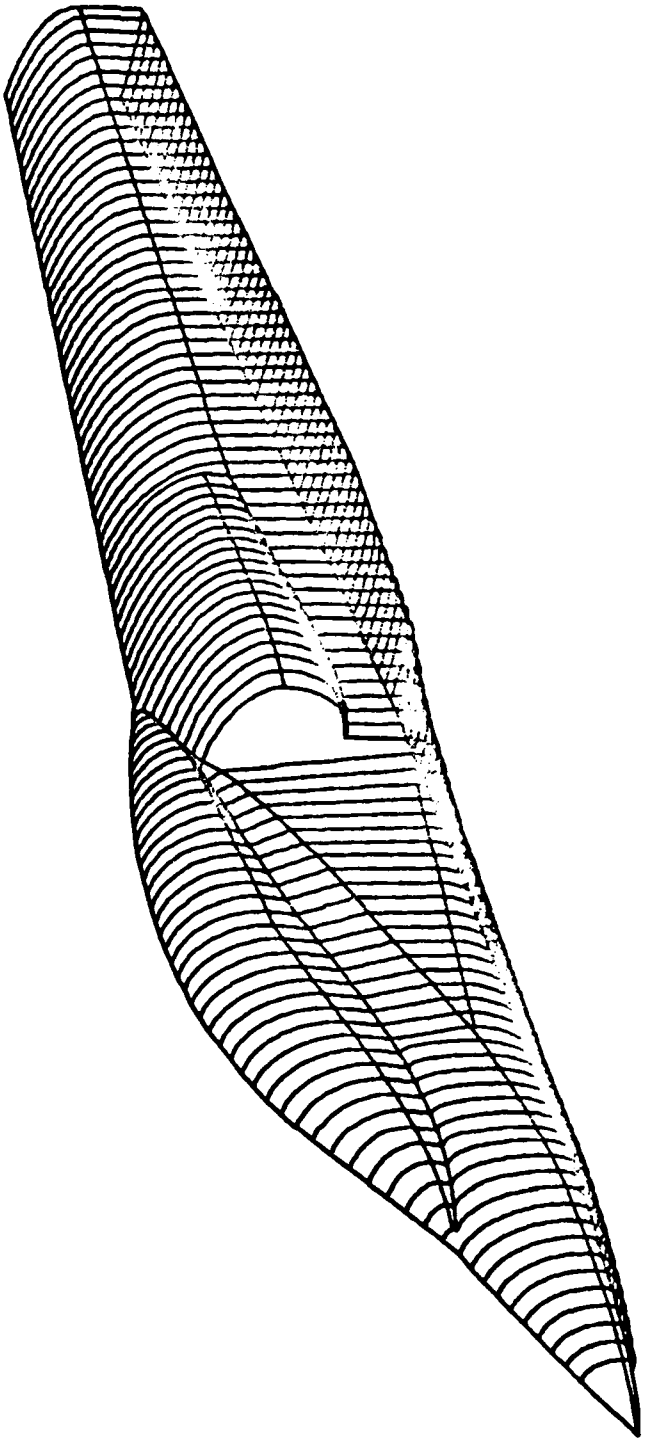
GRUMMAN


CROSS-SECTION BUILT UP FROM
INTERSECTING ARCS
LONGITUDINAL CONSISTENCY
Z-AXIS
Y-AXIS
GRUMMAN

DETAILED CROSS-SECTION GEOMETRY

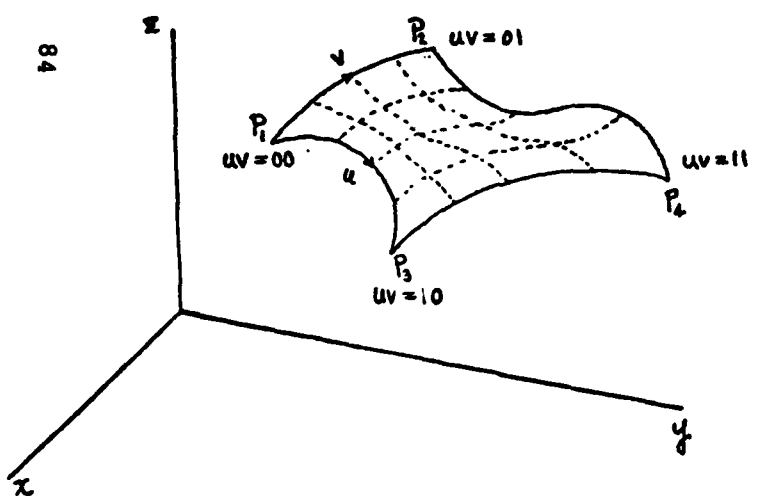


GRUMMAN

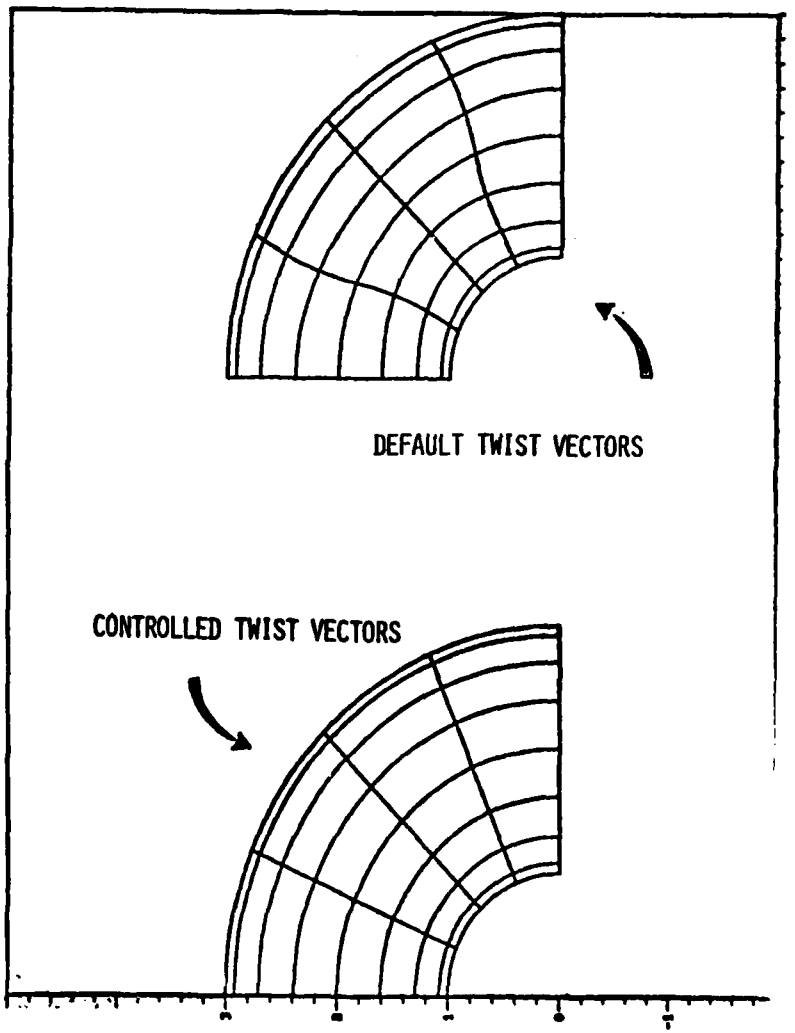


X6 BI-CUBIC PATCH SURFACE

$$P(u,v) = (u^3\ u^2\ u\ 1)\ M^T \begin{bmatrix} P_1 & P_2 & P_{v_1} & P_{v_2} \\ P_3 & P_4 & P_{v_3} & P_{v_4} \\ P_{u_1} & P_{u_2} & P_{uv_1} & P_{uv_2} \\ P_{u_3} & P_{u_4} & P_{uv_3} & P_{uv_4} \end{bmatrix} M \begin{bmatrix} v^3 \\ v^2 \\ v \\ 1 \end{bmatrix}$$



X6 TWIST VECTOR CONTROL



X6 SURFACE DATA STRUCTURE

TOF:

POINTS

	X	Y	Z
1	0.0	0.0	0.0
2	2.000	0.0	0.0
3	0.0	1.000	0.0
4	2.000	1.000	0.0
5	0.0	0.0	0.0
6	3.000	0.0	0.0
7	0.0	0.0	0.0
8	0.0	3.000	0.0
9	0.0	0.0	0.0
10	0.0	0.0	1.000

SLOPES

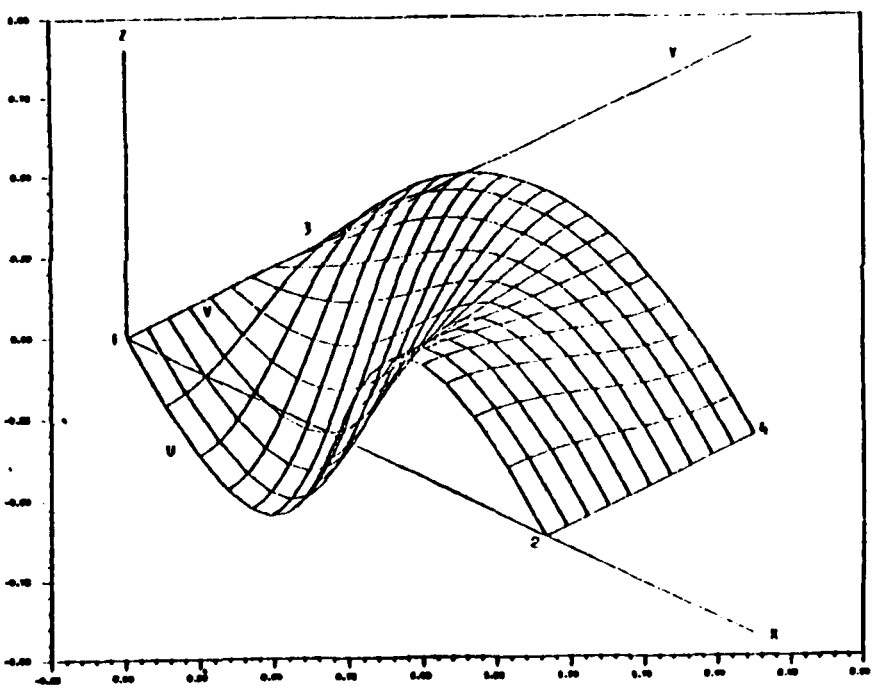
1	4.000	0.0	-4.000
2	4.000	0.0	-4.000
3	2.000	0.0	2.000
4	2.000	0.0	-2.000
5	0.0	1.000	0.0
6	0.0	1.000	0.0
7	0.0	1.000	0.0
8	0.0	1.000	0.0
9	3.000	0.0	0.0
10	3.000	0.0	0.0
11	0.0	3.000	0.0
12	0.0	3.000	0.0
13	0.0	0.0	1.000

LINES

		POINTS		SLOPES		COLOR
1	0	1	2	1	1	1
2	0	3	4	3	4	1
3	0	1	3	5	5	1
4	0	2	4	7	7	1
5	0	5	6	9	9	1
6	0	7	8	11	11	1
7	0	9	10	13	13	1

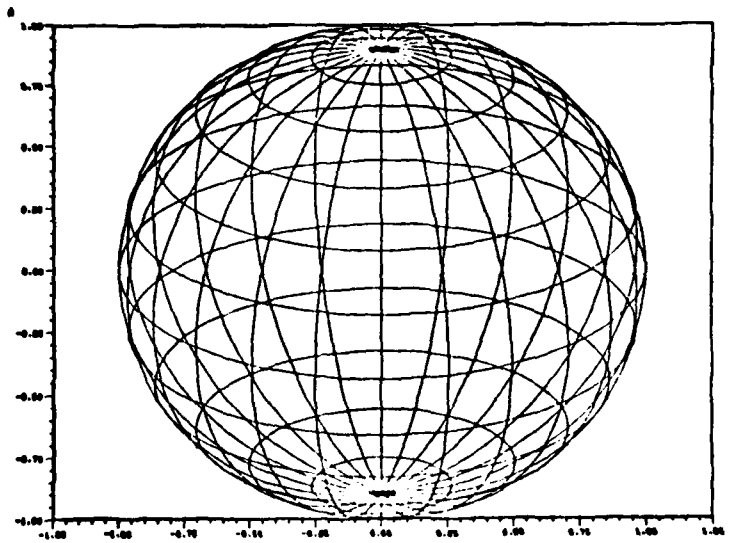
SURFACES

		LINES				TWIST TERMS				SURFACE COLOR		GRID LINES
1	0	1	2	3	4	0	0	0	0	1	1	9 19

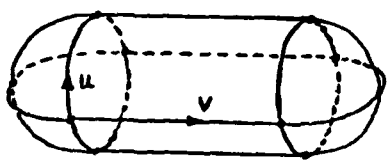


X6 DERIVATIVE VECTOR CODES

0 — CONTINUOUS VECTOR
1 — LINEAR VECTOR
2 — NEIGHBOR VECTOR
3 — NO CONNECTION
4 — EXTERNAL VECTOR
5 — FREE END VECTOR



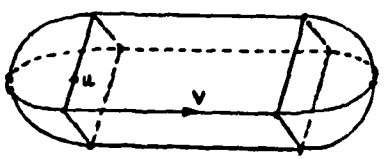
Example 1 ;



4 X 4 NODES

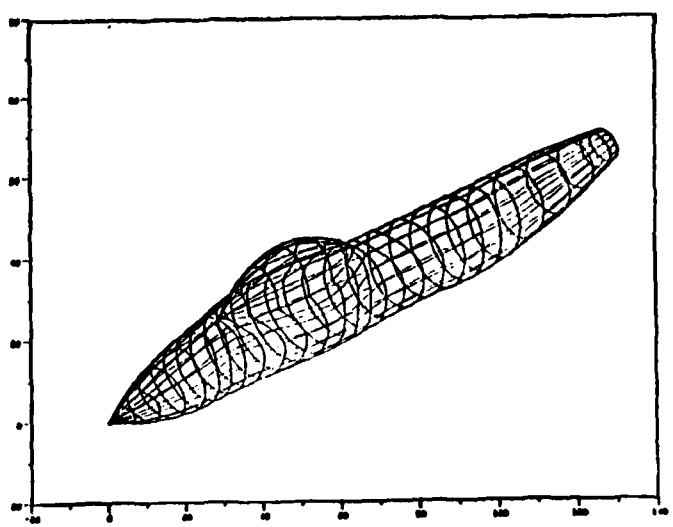
u 00 00 00 00
v 42 11 24 33

Example 2 :

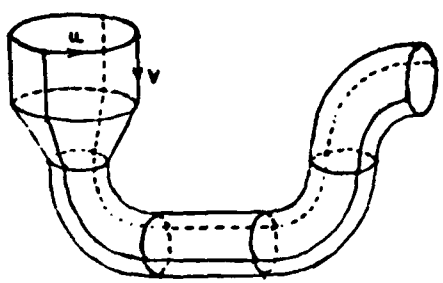


4 X 4 NODES

u 11 11 11 11
v 42 11 24 33



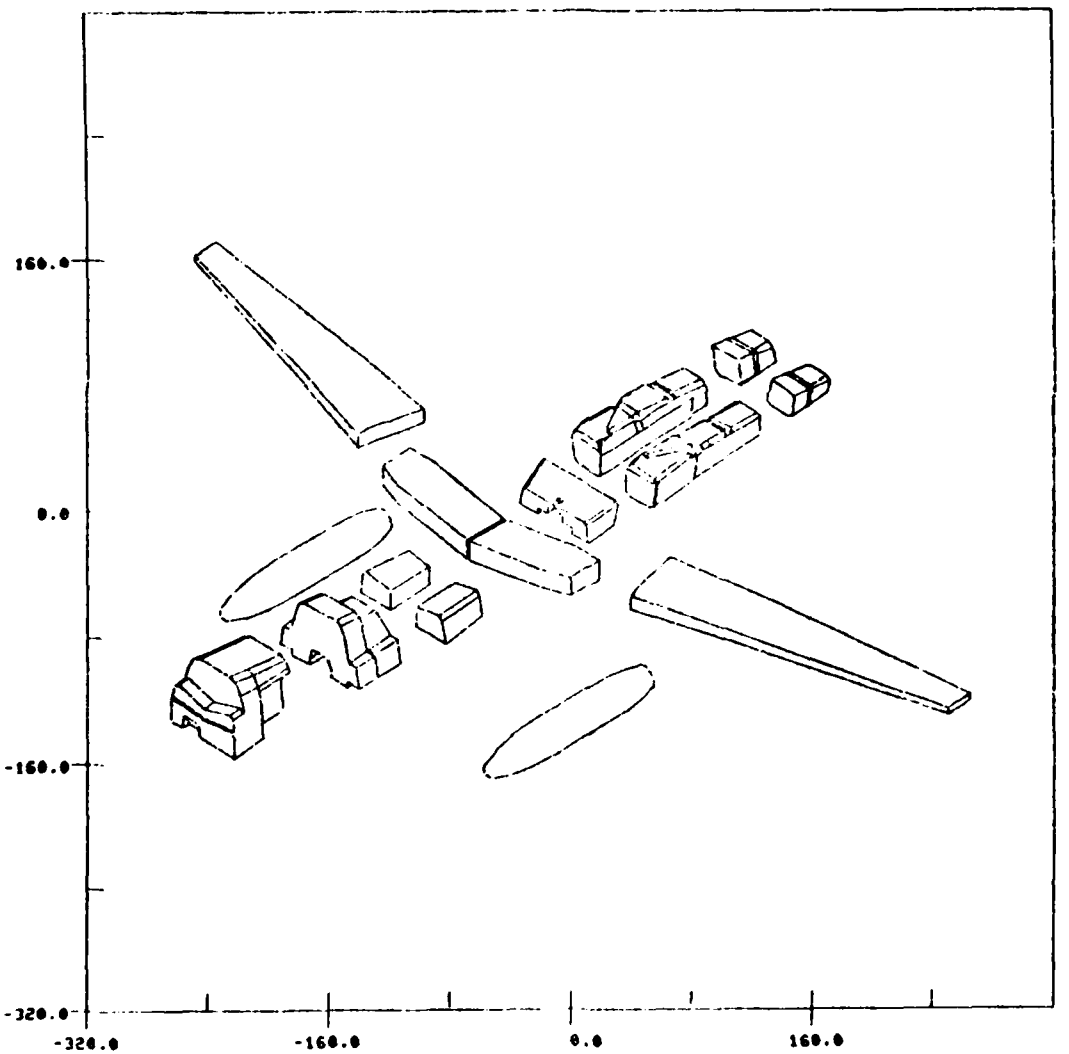
Example 3 :



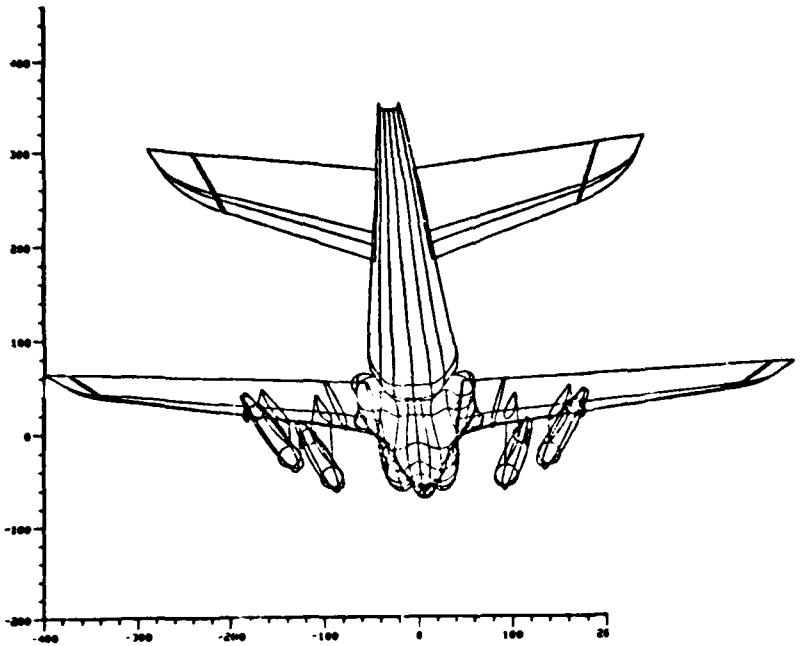
4 X 7 NODES

u 00 00 00 00
v 11 11 42 11 24
24 33

F14 FUEL SYSTEM

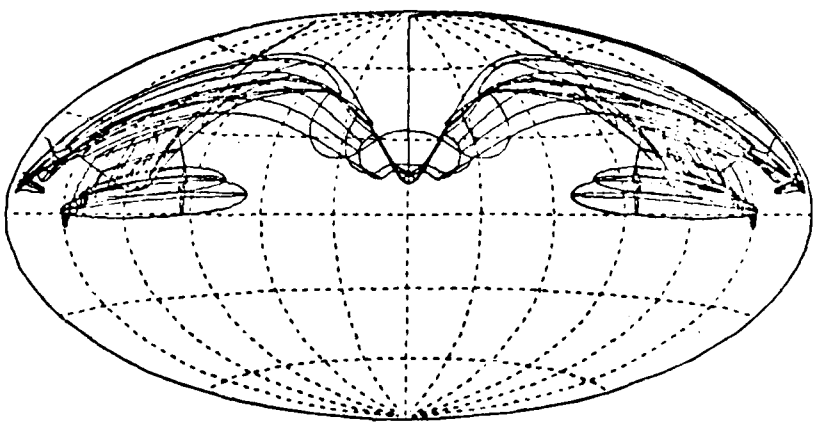


ISOMETRIC



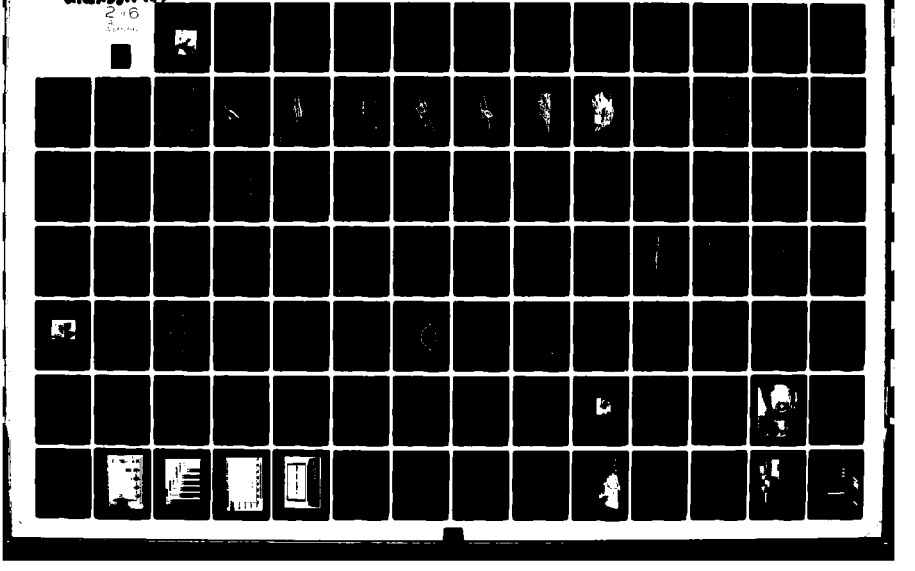
AITOFF VISION PROJECTION PER MIL-STD 850 B

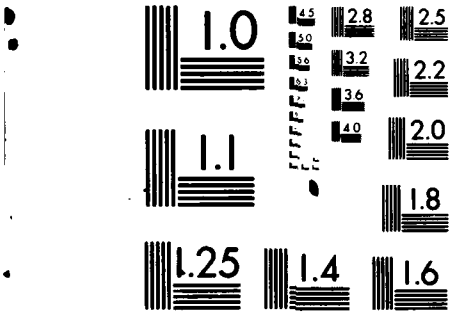
EA6B ANTENNA STUDY



VISION CL DATA
STA 205.500
BL 0.0
UL 25.300
AZ 0.0
EL 6.000

AD-A113 556 JOINT TECHNICAL COORDINATING GROUP ON AIRCRAFT SURVIV--ETC F/G 1/3
PROCEEDINGS, A WORKSHOP IN SURVIVABILITY AND COMPUTER-AIDED DES--ETC(U)
1981
UNCLASSIFIED JTCG/AS-81-D-001 NL





MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

FAIRCHILD REPUBLIC COMPANY'S PRIME ACTIVITY: AN INTEGRATED APPROACH TO CAD AND CAM

Rocco Ruggiero
Manager Analytical Services
Fairchild Republic Company
Farmingdale, New York

ROCCO RUGGIERO
FAIRCHILD REPUBLIC COMPANY

FAIRCHILD REPUBLIC COMPANY'S PRIME ACTIVITY: AN INTEGRATED APPROACH TO CAD AND CAM

Rocco Ruggiero
Manager Analytical Services
Fairchild Republic Company
Farmingdale, New York

The Fairchild Republic Company, since the early part of 1979, has undertaken a concentrated effort to automate its engineering design process and to completely integrate it with manufacturing operations. This effort is embodied in its PRIME program, PR for Integrating Manufacturing and Engineering in an interactive mode. The PRIME program, whose ultimate objective is a complete integrated factor, consists of an ICAD project, a CAD/CAM operation and a Data Base Management (DBM) Section. ICAD seeks to convert technical analysis application software from batch mode to interactive and to add graphic capability. This conversion is paced to the aircraft design process with the first accomplishments being in the aircraft sizing and trade study process. The modules comprising this process are described. The CAD/CAM operations include two Computervision "turnkey" systems with 10 work stations. Also, a study of a CADAM alternative is underway. The DBM Section is developing hardware and software for managing a comprehensive technical data base which will have at its core a geometry data base. Details of all of this are given as well as examples of various graphics developments: machining drawings, tool path control, FEM model development, vehicle design depiction. The dynamic graphics developments in FRC's TASEM/MAPS program, which advances the state-of-the-art in computer graphic depiction of combat operations, are also illustrated.

FAIRCHILD REPUBLIC COMPANY'S PRIME ACTIVITY: AN INTEGRATED APPROACH TO CAD AND CAM

FAIRCHILD
REPUBLIC COMPANY
FARMINGDALE, L.I., NEW YORK 11735

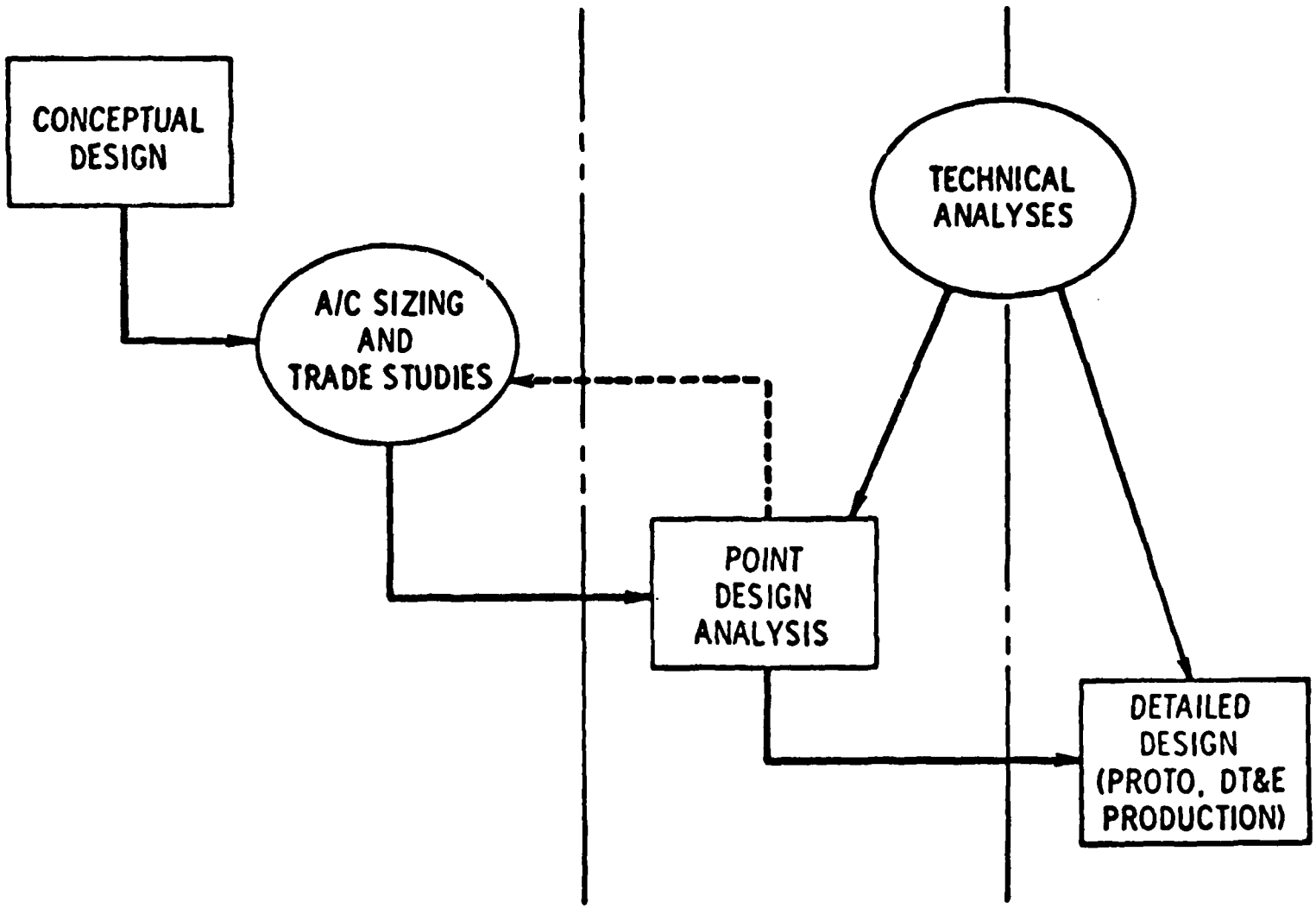
PROGRAM TO INTEGRATE MANUFACTURING AND ENGINEERING (PRIME)

- THE INITIAL STEP AT FRC TOWARD OVERALL FACILITY AUTOMATION
- ESTABLISHED IN 1979 IN THE ENGINEERING DEPARTMENT
- GOAL: OPTIMIZE THE FRC DESIGN-TO-MANUFACTURING PROCESS THROUGH EXPLOITATION OF STATE-OF-THE-ART COMPUTER-BASED CAPABILITIES
- BENEFITS:
  - MAKE CURRENT EMPLOYEES MORE PRODUCTIVE AND MOTIVATED
  - REDUCES REQUIREMENTS TO HIRE AND TRAIN NEW EMPLOYEES
  - ATTRACTS A BETTER CLASS OF YOUNG PROFESSIONALS TO FRC
  - EXPEDITES THE TRAINING OF ALL PERSONNEL

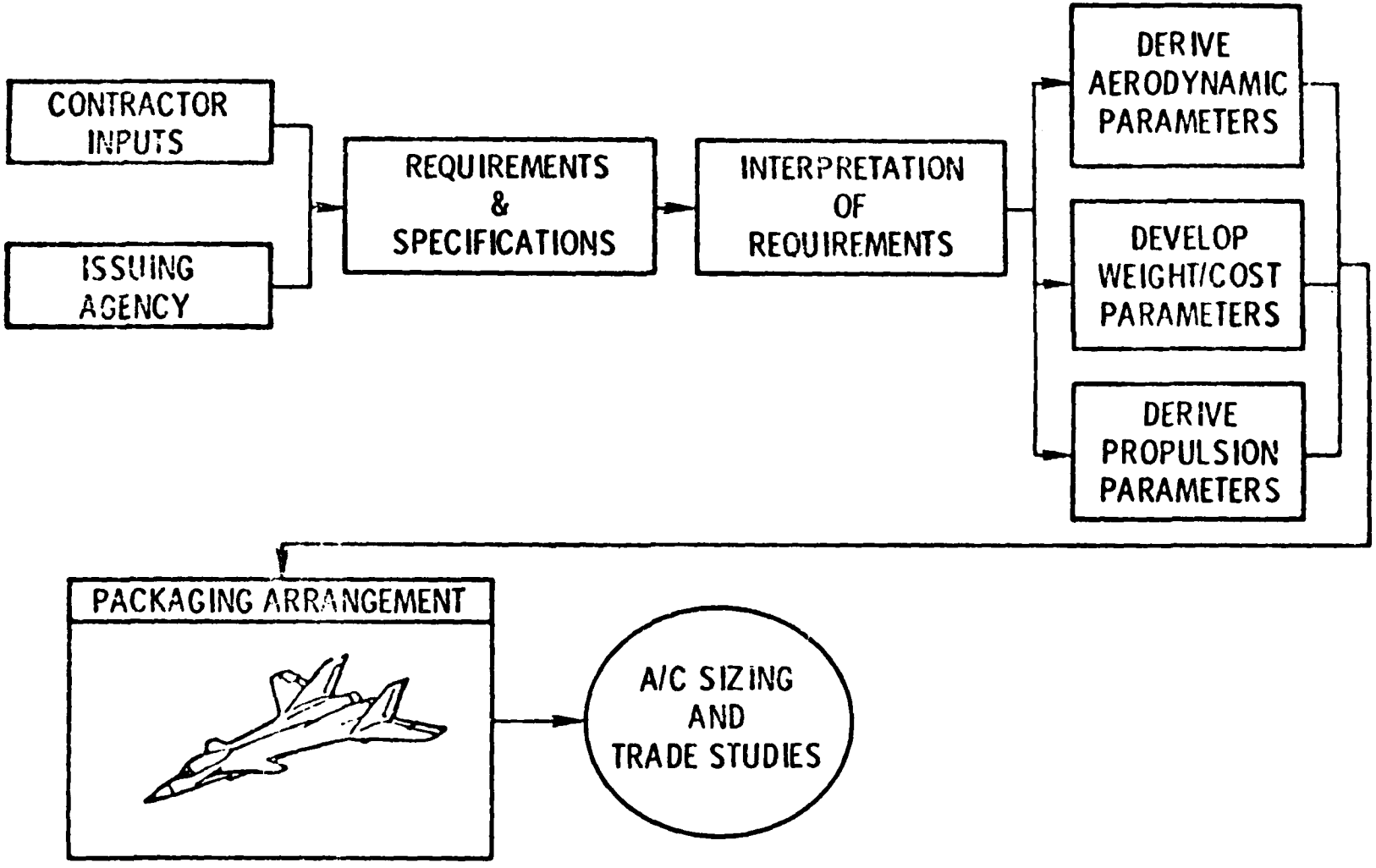
PRIME IS COMPRISED OF:

- INTERACTIVE COMPUTER-AIDED DESIGN (ICAD) PROJECT
- COMPUTER-AIDED DESIGN/COMPUTER-AIDED MANUFACTURING (CAD/CAM) PROJECT
- DATA BASE MANAGEMENT SECTION

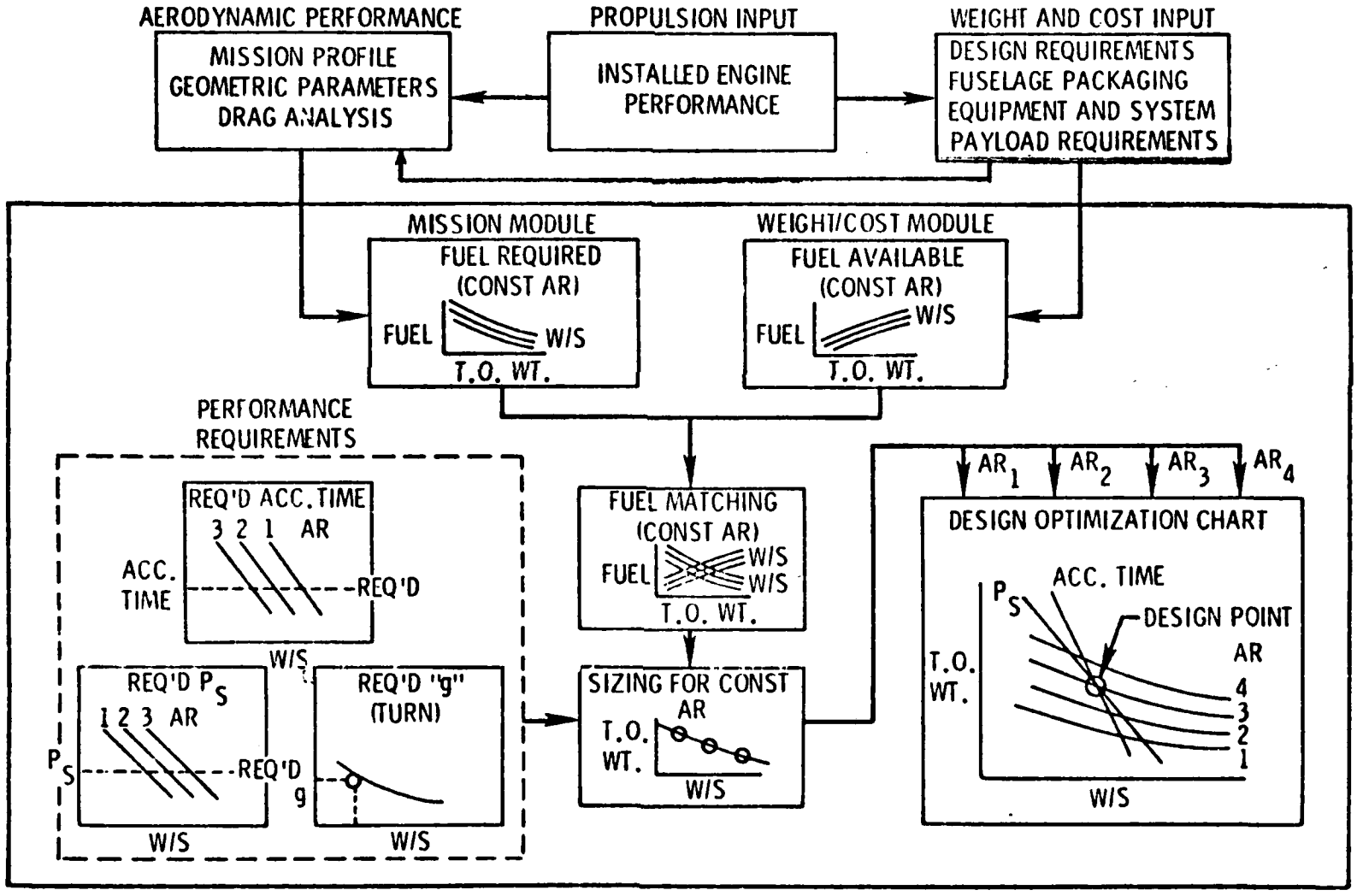
OVER-ALL DESIGN PROCESS



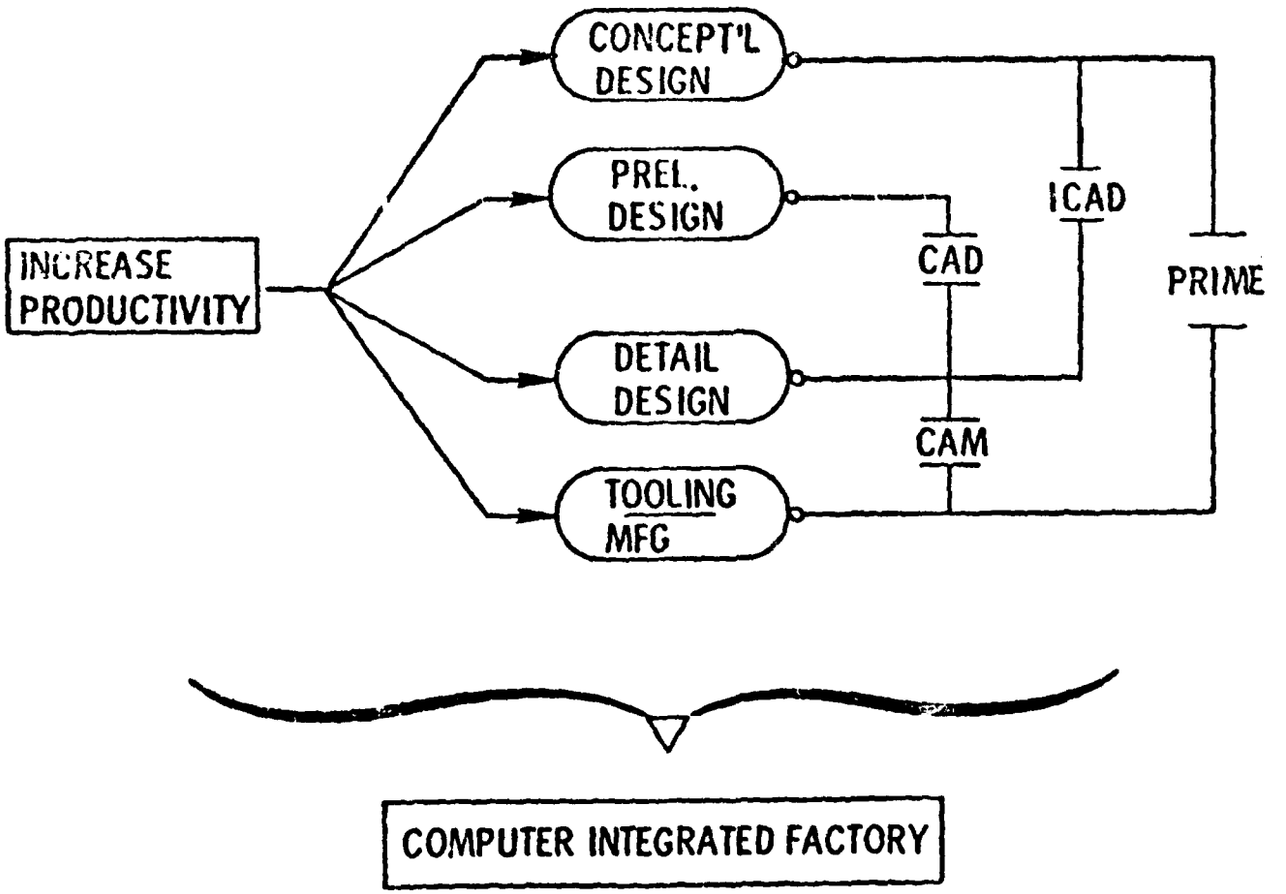
CONCEPTUAL DESIGN PROCESS



AIRCRAFT SIZING/TRADE-STUDY PROCESS



CAD/CAM IS PART OF PRIME



PROJECT ROLES - ELEMENTS OF PRIME

ICAD: IMPROVE CONCEPTUAL, PRELIMINARY AND DETAILED DESIGN FUNCTIONS THROUGH CONVERSION OF TECHNICAL ENGINEERING TO INTERACTIVE, INTEGRATED ENVIRONMENT

CAD/CAM: ESTABLISH INTERACTIVE COMPUTER GRAPHICS SYSTEMS TO SUPPORT ENGINEERING/MANUFACTURING IN PRELIMINARY, DETAILED DESIGN, NUMERICAL CONTROL & TOOLING FUNCTIONS

DATA BASE MGT. SECTION:

INSTALLATION AND MAINTENANCE OF A DATA BASE SYSTEM TO SUPPORT ICAD AND CAD/CAM ACTIVITIES

THE CURRENT ICAD ENVIRONMENT

GRAPHICS CRT TERMINALS & SUPPORTING EQUIPMENT (TEXTRONIX)
- 3 "DUMB" (4014) TERMINALS
- 2 INTELLIGENT (4051/2) TERMINALS
- GRAPHICS (4081) SYSTEM W/DISC DRIVE
- 2 HARD COPY UNITS
- 2 PLOTTERS
- 1 DIGITIZER

ALPHANUMERIC TERMINALS
- 5 LEAR-SIEGLER CRT TERMINALS
- 2 TTY TERMINALS
- ITT-COURIER INFO DISPLAY SYSTEM (W/9 TERMINALS + PRINTER)

COMPUTER SUPPORT PROVIDED BY CORPORATE HQ IBM 4341
- VIA TELEPHONE COMMUNICATIONS LINES
- OPERATING SYSTEM: OS/MVT (W/TSO) CONVERTING TO VM/CMS (AND VS1)

ICAD PROJECT - ACCOMPLISHMENTS

COMPONENT MODULES OF AIRCRAFT SIZING PROCESS MADE INTERACTIVE
- AEROCHARACTERISTICS PROGRAM
- PROPULSION MODULE(S)
- WEIGHTS/COST PROGRAM
- MISSION PROGRAM

CONVERSION OF CRITICAL ANALYSIS PROGRAMS TO INTERACTIVE MODE
- VORTEX LATTICE SUBSONIC LOADS PROGRAM
- SHEARS, MOMENTS, TORQUES COMPUTATIONS
- FUSELAGE SHEARS AND BENDING MOMENTS

DEVELOPMENT OF AIRCRAFT MODELING CAPABILITY
- ACQUISITION, CONVERSION TO IBM, OF NASA GEMPAK PROGRAM
- ENHANCEMENT OF GEMPAK TO ALLOW PLOTTING AND MULTI-BODIES

DEVELOPMENT OF ICAD EXECUTIVE ROUTINE FOR CMS ENVIRONMENT

FORMATION OF ICAD ADVISORY COMMITTEE
- PROMOTES USER INVOLVEMENT IN
  - ICAD TASK PLANNING
  - TRAINING
  - SELECTION OF ICAD TASK MONITORS
- MEETINGS HELD WEEKLY

ICAD PROJECT - CURRENT ACTIVITIES

MOVE OF INTERACTIVE PROCESSING TO CMS ENVIRONMENT
- TRAINING OF PROGRAMMERS NEARING COMPLETION
- CONVERSION OF PROGRAMS UNDERWAY
- TRAINING OF USERS INITIATED

ENHANCE/IMPROVE SIZING PROCESS

AIRCRAFT MODELING CAPABILITY DEVELOPMENT
- ENHANCEMENT OF GEMPAK (MULTI-BODY PLOTTING; MASS PROPERTIES)
- DEFINITION OF REQTS FOR COMMON GEOMETRY DATA BASE

TRAINING/CONSULTATION FOR TECHNICAL ENGINEERING ANALYSTS IN:
- UTILIZATION OF LOCAL AND REMOTE INTERACTIVE CAPABILITIES
- OPERATION/DEVELOPMENT OF LOCAL AND SPECIALIZED PROGRAMS

IMPLEMENTATION OF INTERACTIVE FEM CAPABILITY

DEVELOP/IMPROVE AUTOMATED ELEMENTS OF CONCEPTUAL/PRELIMINARY DESIGN PROCESS

DEVELOPMENT OF NASTRAN POST-PROCESSORS

INSTALLATION OF IMPROVED VERSION OF VORTEX-LATTICE PROGRAM

ICAD PROJECT - PLANNED ACTIVITIES

IN CONJUNCTION WITH ICAD ADVISORY COMMITTEE, ESTABLISH TASKS TO:
- CONVERT SELECTED ANALYSES PROGRAMS TO INTERACTIVE MODE
- ACQUIRE/DEVELOP SOFTWARE TO FILL GAPS IN AUTOMATED DESIGN PROCESS
- TRAIN/FAMILIARIZE USERS IN OPERATION OF ICAD-DEVELOPED SOFTWARE
- DOCUMENT ICAD-DEVELOPED SOFTWARE

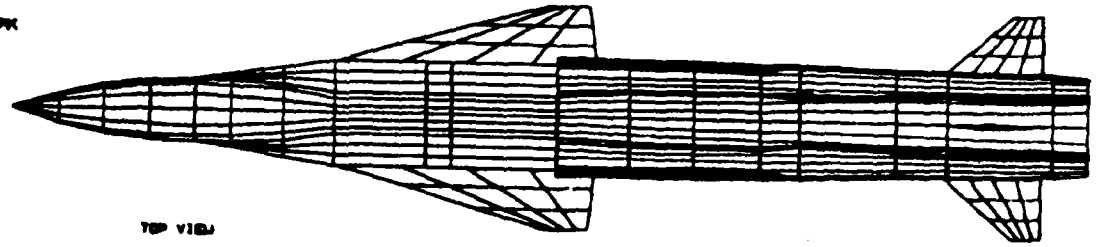
CONTINUE DEVELOPMENT OF GEOMETRY MODELING CAPABILITY
- ESTABLISH GEOMETRY DATA BASE
- INSTALL AS INTEGRAL PART OF A/C SIZING PROCESS
- INTERFACE WITH OTHER TECHNICAL ANALYSES PROGRAMS

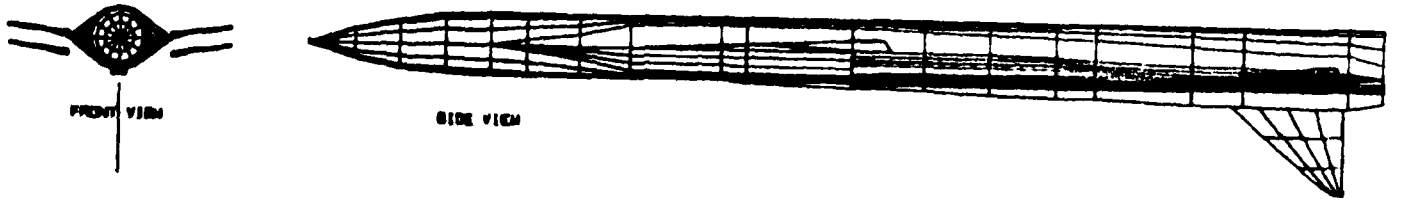
INSTALLATION OF ICAD-DEVELOPED SOFTWARE INTO COMPUTER PROGRAM CONTROL SYSTEM USING ICAD EXECUTIVE ROUTINE

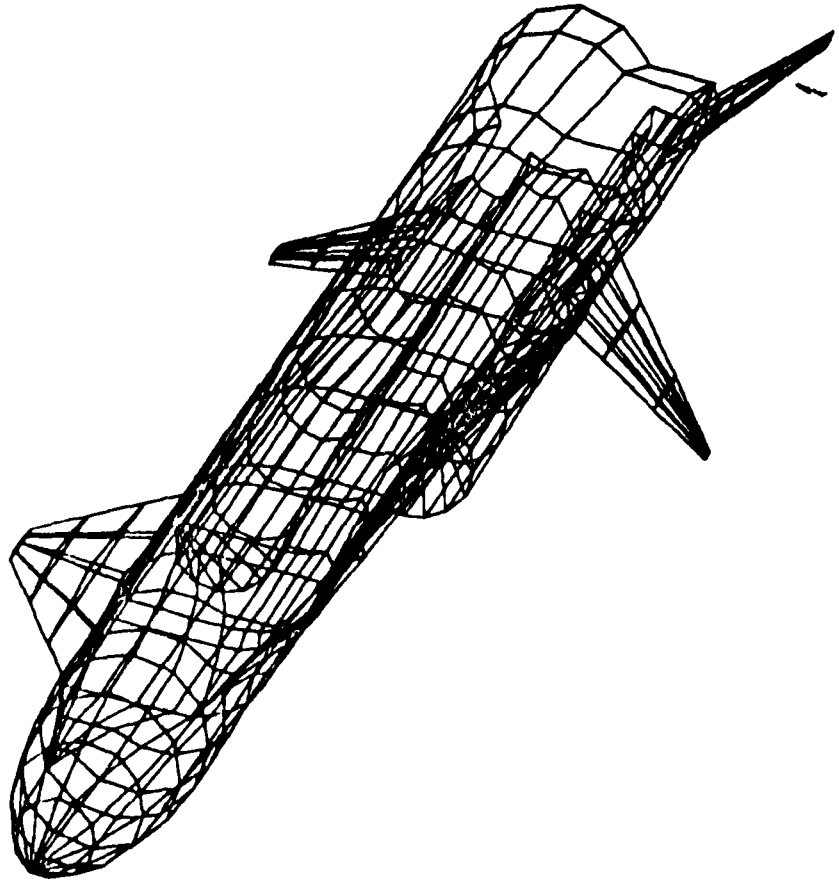
AUGMENT ELEMENTS OF DESIGN PROCESS WITH ADDITIONAL INTERACTIVE GRAPHICS DISPLAYS

ACQUIRE ADDITIONAL INTERACTIVE TERMINALS & SUPPORTING PERIPHERALS (1981-85)
- 9 INTELLIGENT GRAPHICS TERMINALS WITH FLOPPY DISC DRIVES
- 3 HARD-COPY UNITS, PLOTTER, DIGITIZER
- IBM 3270 INFO DISPLAY SYSTEM W/20 CRT TERMINALS + PRINTER

CONVERSION OF PROCESSING TO LOCAL COMPUTER FACILITY







AXES ROTATIONS IN DEGREES

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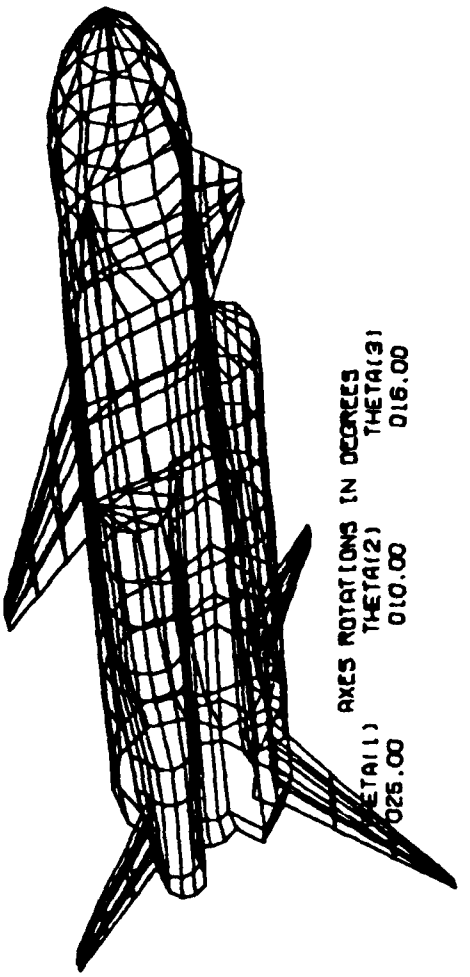
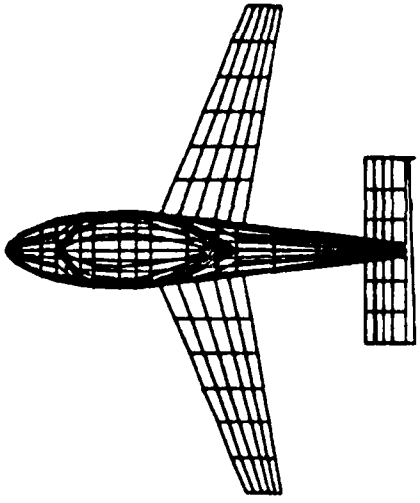

AXES ROTATIONS IN DEGREES
THETA(1)
025.00
THETA(2)
010.00
THETA(3)
016.00

MODELING FOR DEMPAK
TRAINER PROPOSAL

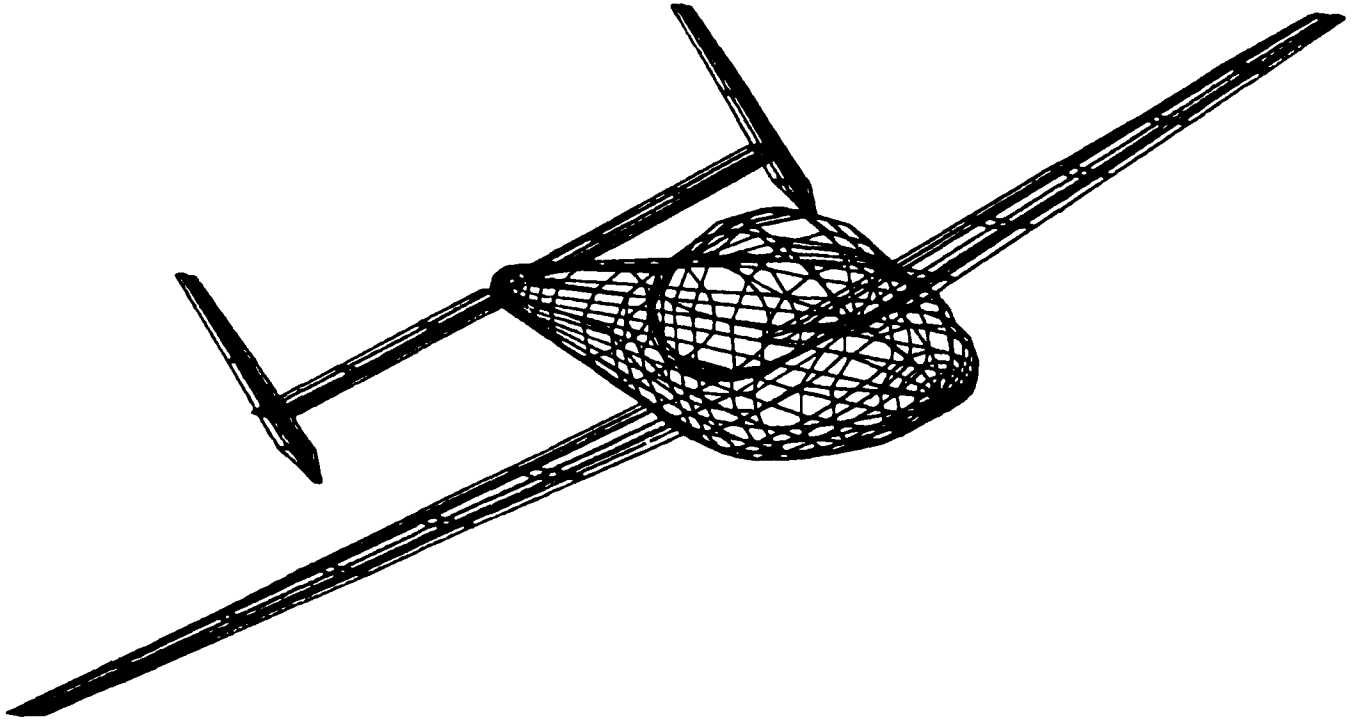


TOP VIEW

FRONT VIEW

SIDE VIEW

MODELING FOR DEMPAK
TRAINER PROPOSAL



AXES ROTATIONS IN DEGREES

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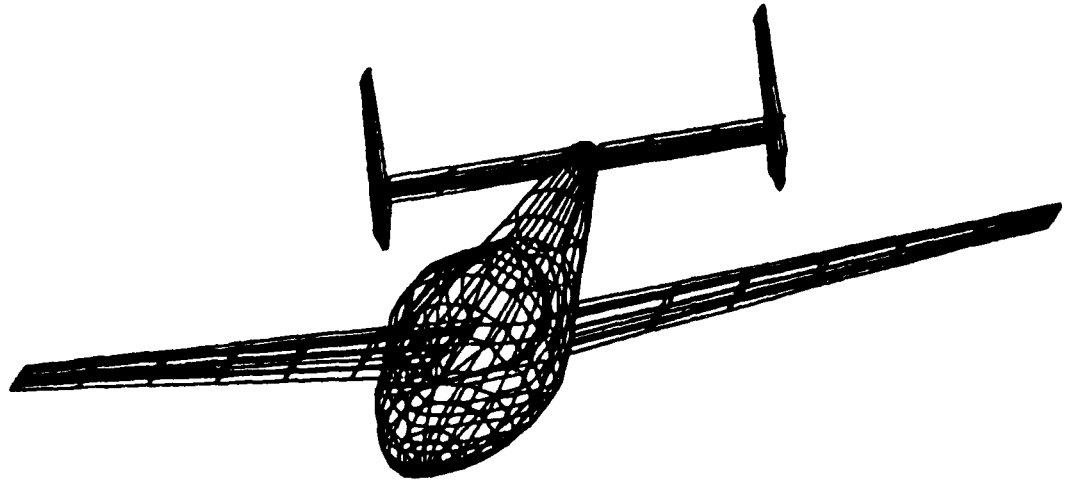
MODELING FOR GDPPAK
TRAINER PROPOSAL



AXES ROTATIONS IN DEGREES

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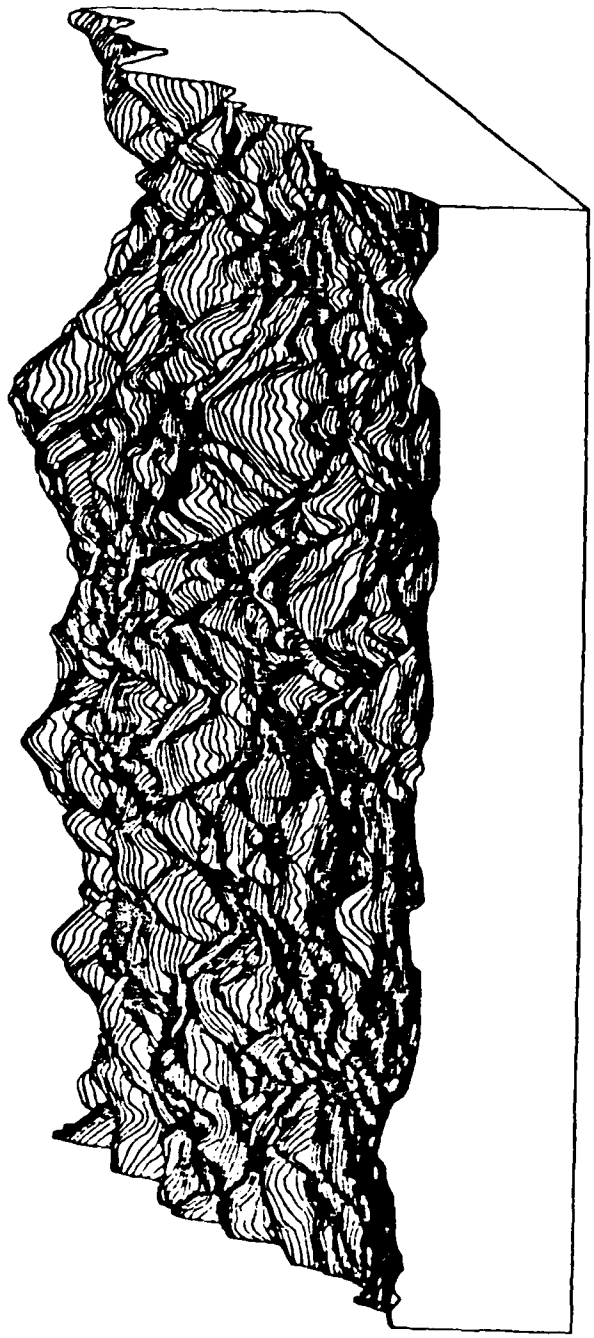
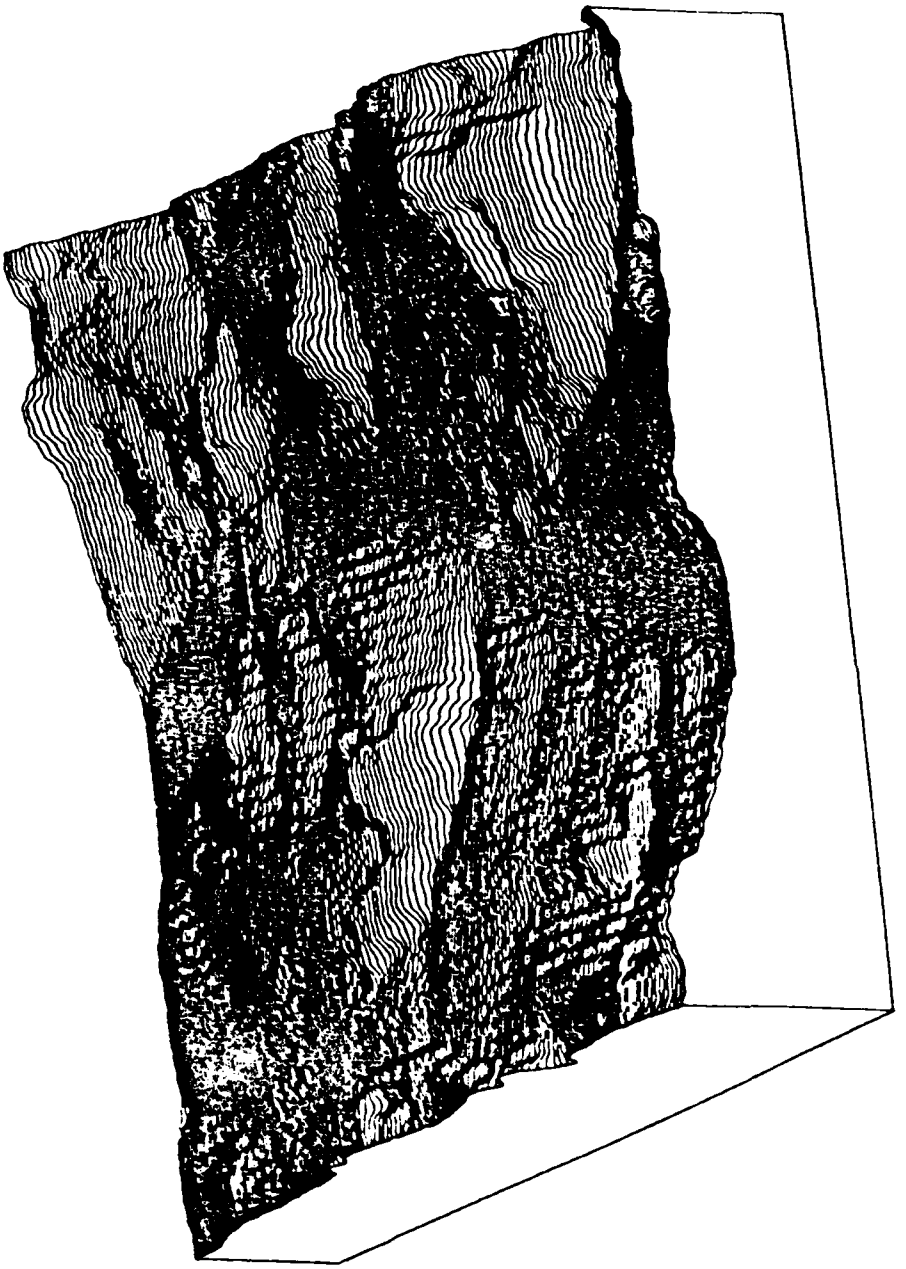
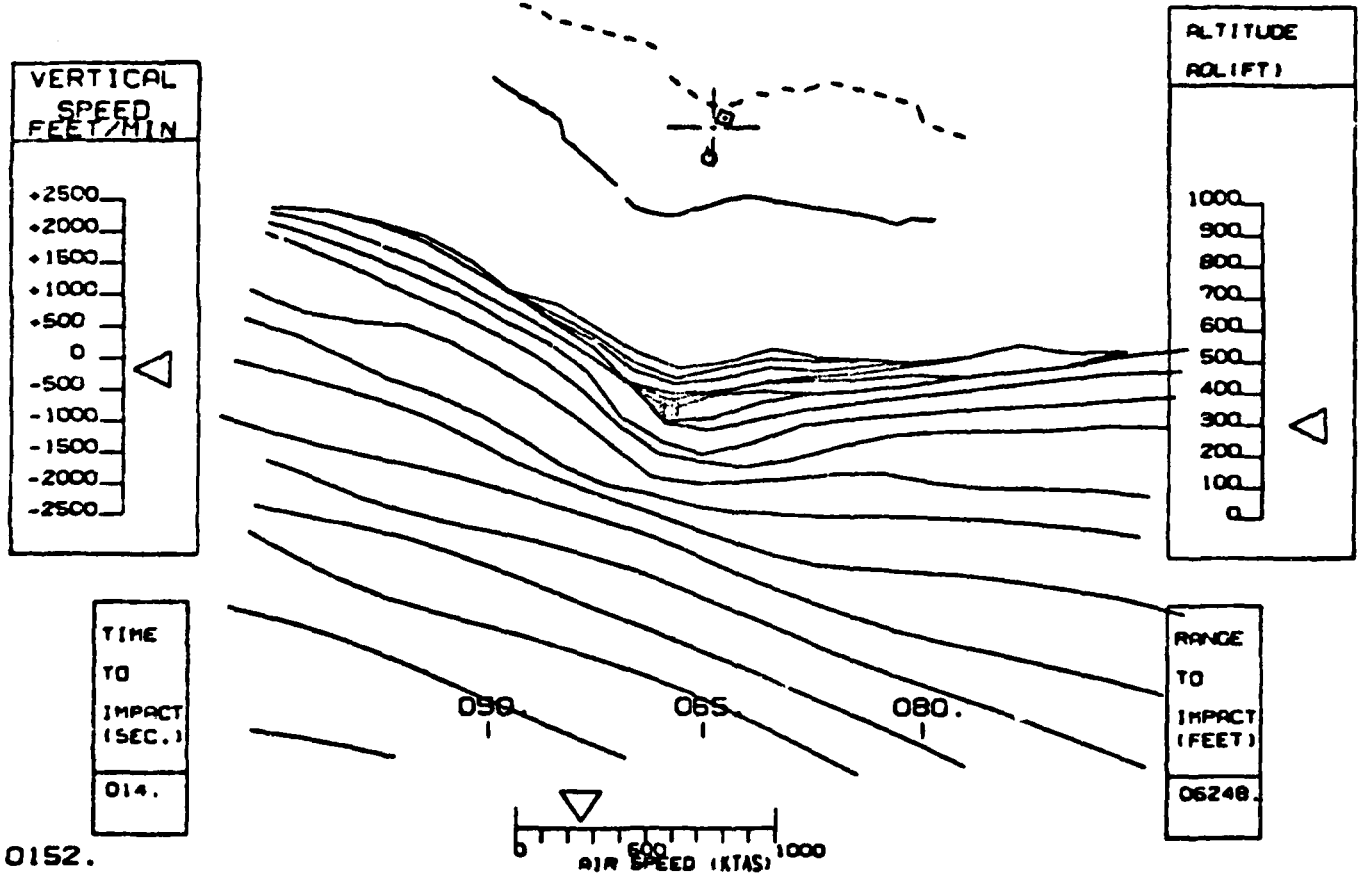
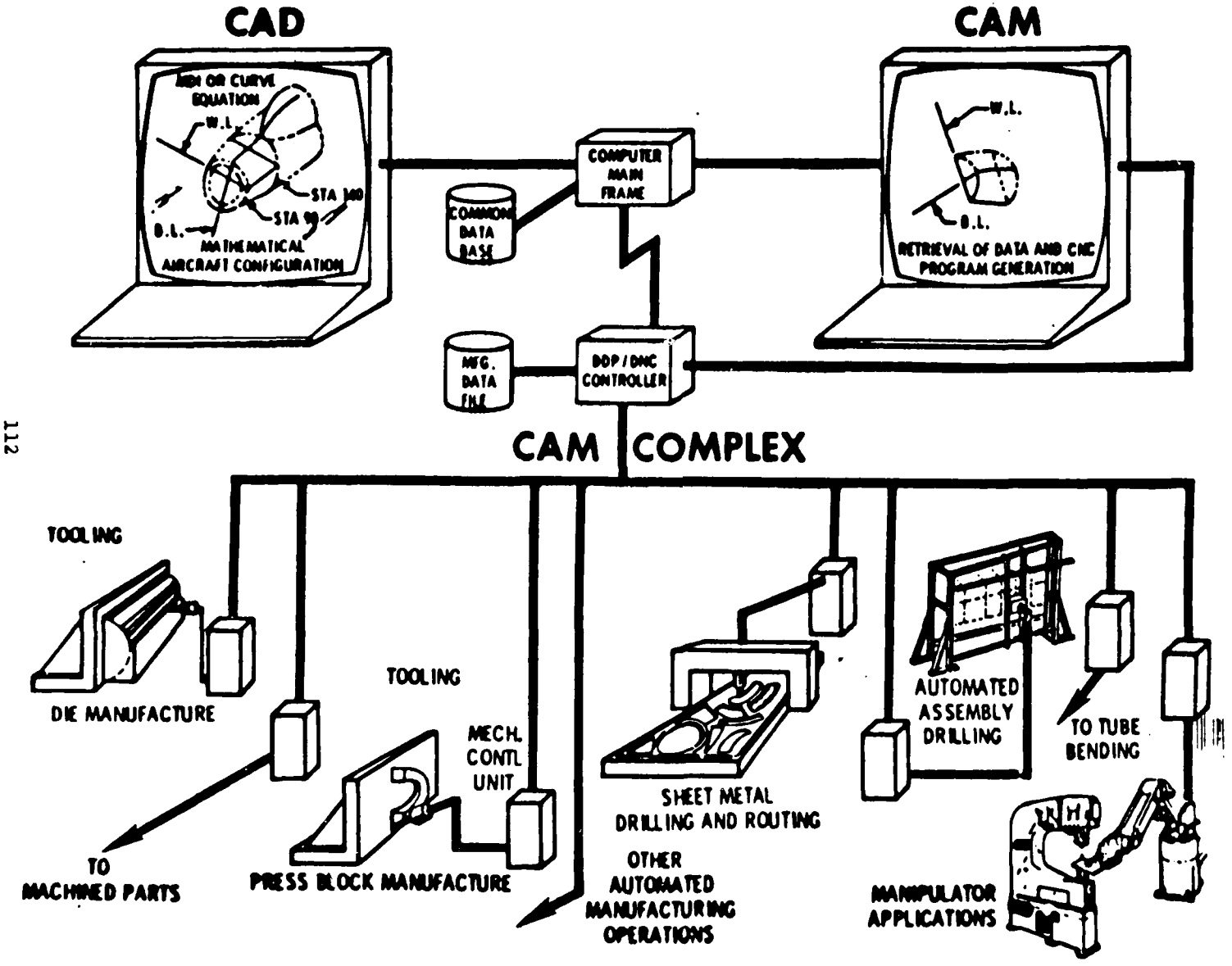
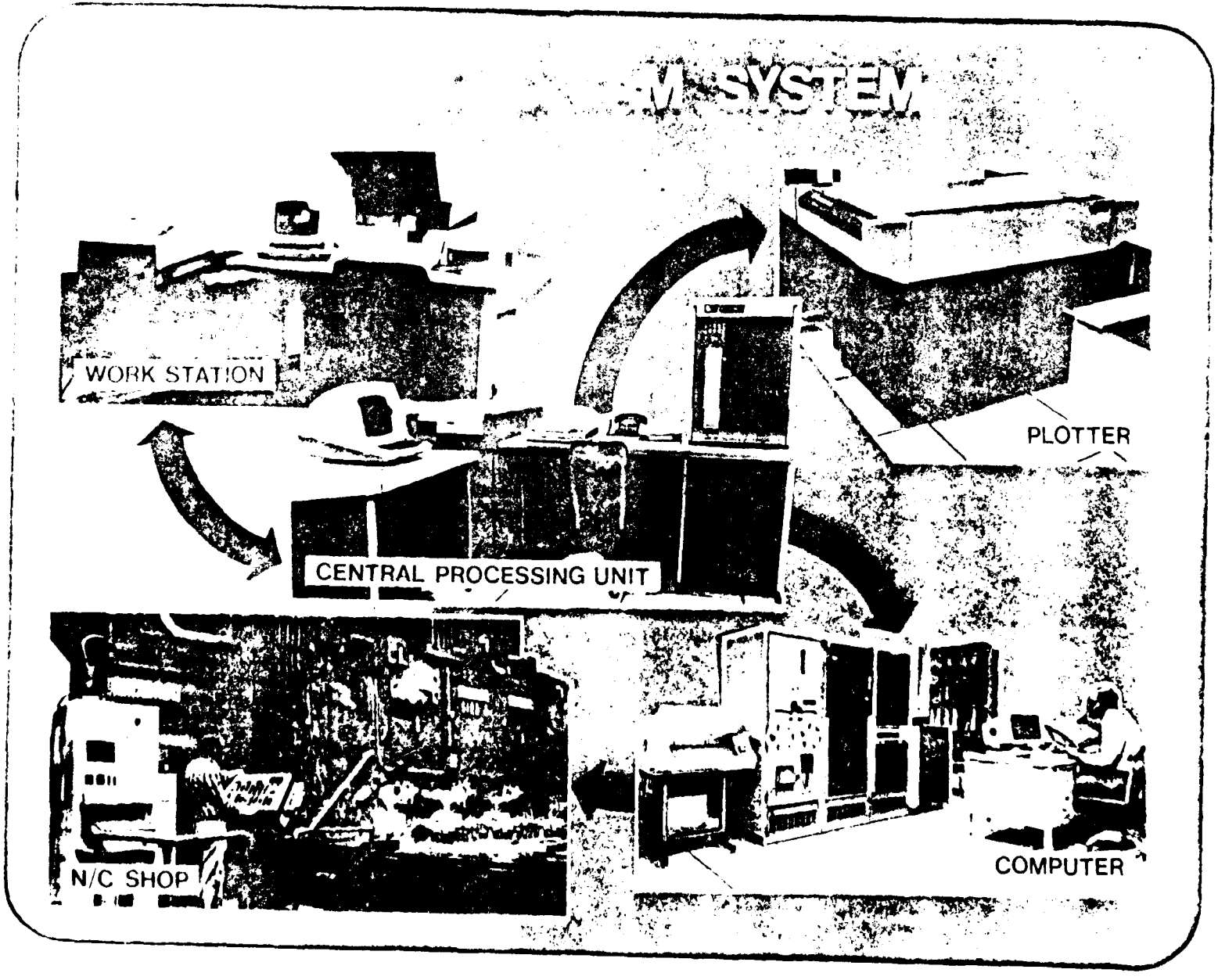



NORTH


VERTICAL SPEED FEET/MIN
+2500
+2000
+1500
+1000
+500
0
-500
-1000
-1500
-2000
-2500
ALTITUDE AGL(FT)
1000
900
800
700
600
500
400
300
200
100
0
TIME TO IMPACT (SEC.)
014.
0152.
090.
085.
080.
RANGE TO IMPACT (FEET)
06248.
0
600
1000
AIR SPEED (KTAS)


CAD
CAM
W.L.
STA
B.L.
MATHEMATICAL AIRCRAFT CONFIGURATION
COMPUTER MAIN FRAME
COMMON DATA BASE
MFG. DATA FILE
DDP/DNC CONTROLLER
RETRIEVAL OF DATA AND CNC PROGRAM GENERATION
CAM COMPLEX
TOOLING
DIE MANUFACTURE
TOOLING
MECH. CONTL UNIT
TO MACHINED PARTS
PRESS BLOCK MANUFACTURE
SHEET METAL DRILLING AND ROUTING
OTHER AUTOMATED MANUFACTURING OPERATIONS
AUTOMATED ASSEMBLY DRILLING
TO TUBE BENDING
MANIPULATOR APPLICATIONS


M-SYSTEM
WORK STATION
PLOTTER
CENTRAL PROCESSING UNIT
N/C SHOP
COMPUTER

FRC CAD/CAM System

The heart of the CAD/CAM system is a Computervision Graphics System consisting of a Central Processing Unit, which controls all the logical and arithmetic functions, a disk drive which can store up to 300 million characters of immediately accessible filed information, and a magnetic tape drive, used as auxiliary storage of data not instantaneously retrievable.

Input to the CAD/CAM system is created at the Work Stations by a graphics operator using a light pen and digitizer and/or an alphanumeric CRT teledisplay unit. The drawing resulting from this input, after processing by the Graphics System, is displayed on the graphics terminal at the Work Station. After revisions and corrections, as necessary, the finished drawing information is stored on the disc and may, as well, be plotted on the automatic plotter.

After the drawing is completed, the Numerical Controls programmer retrieves it for display on the graphics terminal and adds required numerical control machining instructions. This information can then be transmitted, via a physical link, to the Eclipse Computer, where a floppy disc is created which is used as input to the Numerical Control machines; the data is simultaneously stored on another disc connected to the Eclipse.

The Eclipse Computer is physically linked to the Vega III Controllers which automatically drive the machines in the Numerical Controls Shop. The operator of the machine in the shop can either call up the information directly from the Eclipse Computer or feed it into his machine from the floppy disc.

FRC CAD/CAM - PROJECT STATUS

FIRST COMPUTERVISION SYSTEM OPERATIONAL FEBRUARY 1980 (4 WORK STATIONS)

- MANAGER APPOINTED; SYSTEM OPERATORS HIRED
- 3 WORK STATIONS ADDED TO SYSTEM - 1 JULY 1980

SECOND COMPUTERVISION SYSTEM OPERATIONAL JANUARY 1981

- REQUIRED TO SUPPORT 340 COMMUTER PROJECT ACTIVITIES IN 1981
- ADDITION OF 3 WORK STATIONS - TWO SYSTEMS EACH WITH 5 WORK STATIONS
- ADDITIONAL SYSTEM OPERATORS BEING HIRED

DATA COMMUNICATIONS LINK BETWEEN CV SYSTEM AND CORPORATE 4341 - 24 APRIL 1981

TRAINING ACTIVITIES

- 757 TRAINING COMPLETED 1 JUNE 1980 - N/C, LOFT, TOOL DESIGN PERSONNEL
- SF340 TRAINING COMPLETED 1 OCTOBER 1980 - ENGINEERING PERSONNEL
- TOTAL OF 41 PERSONS (24-ENG'G, 17-MFG) TRAINED AS CV SYSTEM USERS
- TRAINING RESUMED 1 APRIL 1981

PRODUCTION ACTIVITIES

- INITIATED 1 JUNE 1980
- N/C, LOFT, TOOL DESIGN, DESIGN ENGINEERING
- 757, SF340, A-10, NGT PROJECTS SUPPORTED
- 120 WORK-STATION HOURS/DAY CURRENTLY SCHEDULED

CAD/CAM COORDINATING COMMITTEE ORGANIZED

- REPRESENTATIVES FROM ALL USER DISCIPLINES
- MEETINGS HELD WEEKLY

FRC CAD/CAM - FUTURE PLANS

PRODUCTION AND TRAINING ACTIVITIES

- CONTINUED SUPPORT OF 757, A-10, NGT PROJECTS IN 1981
- INCREASED SUPPORT OF SF340 COMMUTER PROJECT
- TRAINING OF CV USERS TO CONTINUE THRU 1981

FUTURE CAD/CAM OPTIONS

- COMPUTERVISION
  - 4 ADDITIONAL SYSTEMS BETWEEN 1981 AND 1985
  - TOTAL OF 20 ADDITIONAL WORK STATIONS
- LOCKHEED CADAM ON FRC ENGINEERING COMPUTER
  - 5 - 10 WORK STATIONS OPERATING IN LATE 1981
  - ADDITIONAL WORK STATIONS AVAILABLE IN 1982-3
  - USED FOR SUPPORT OF PROJECTS OTHER THAN SF340

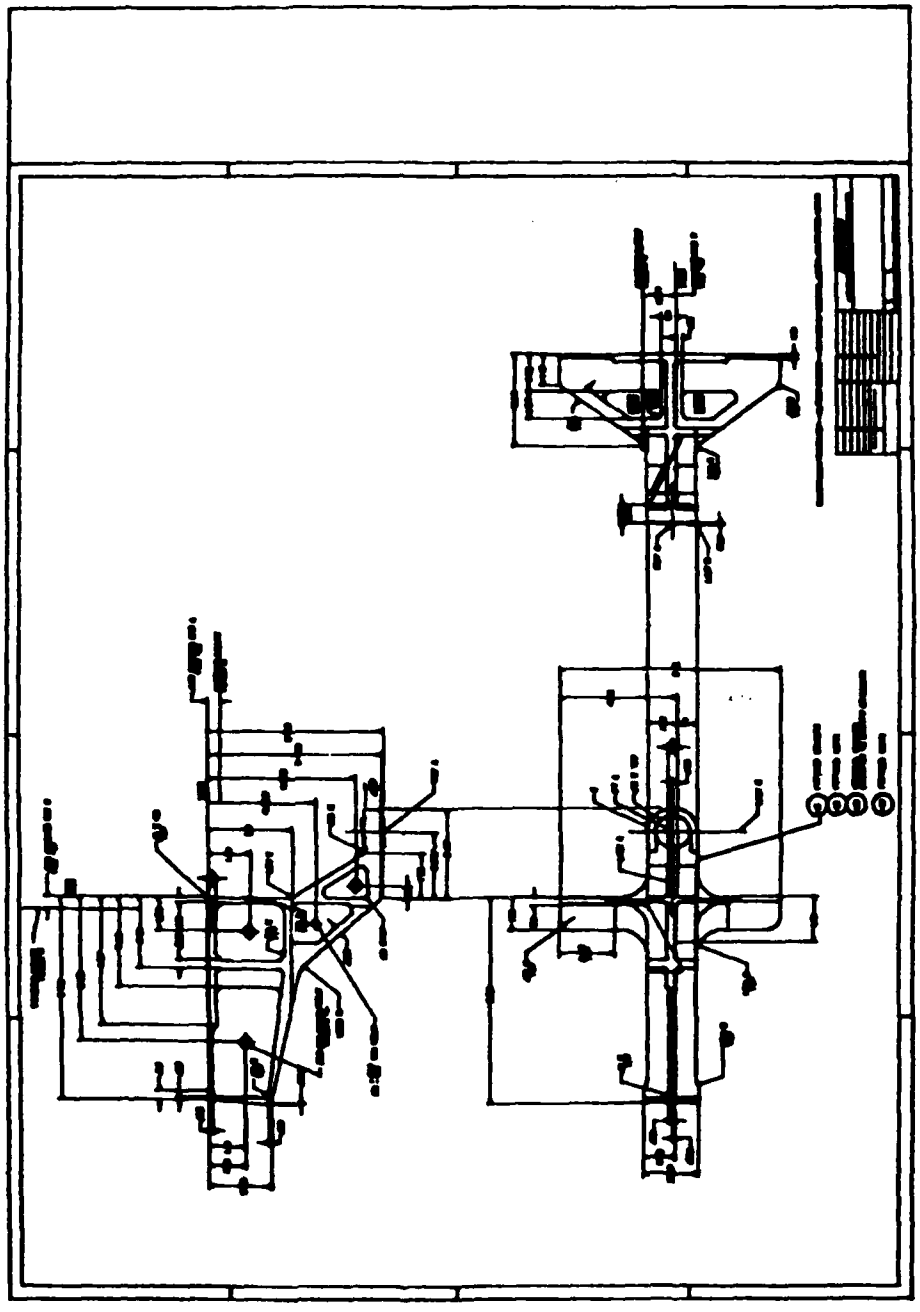
CADAM - FUTURE FRC CAD/CAM OPTION

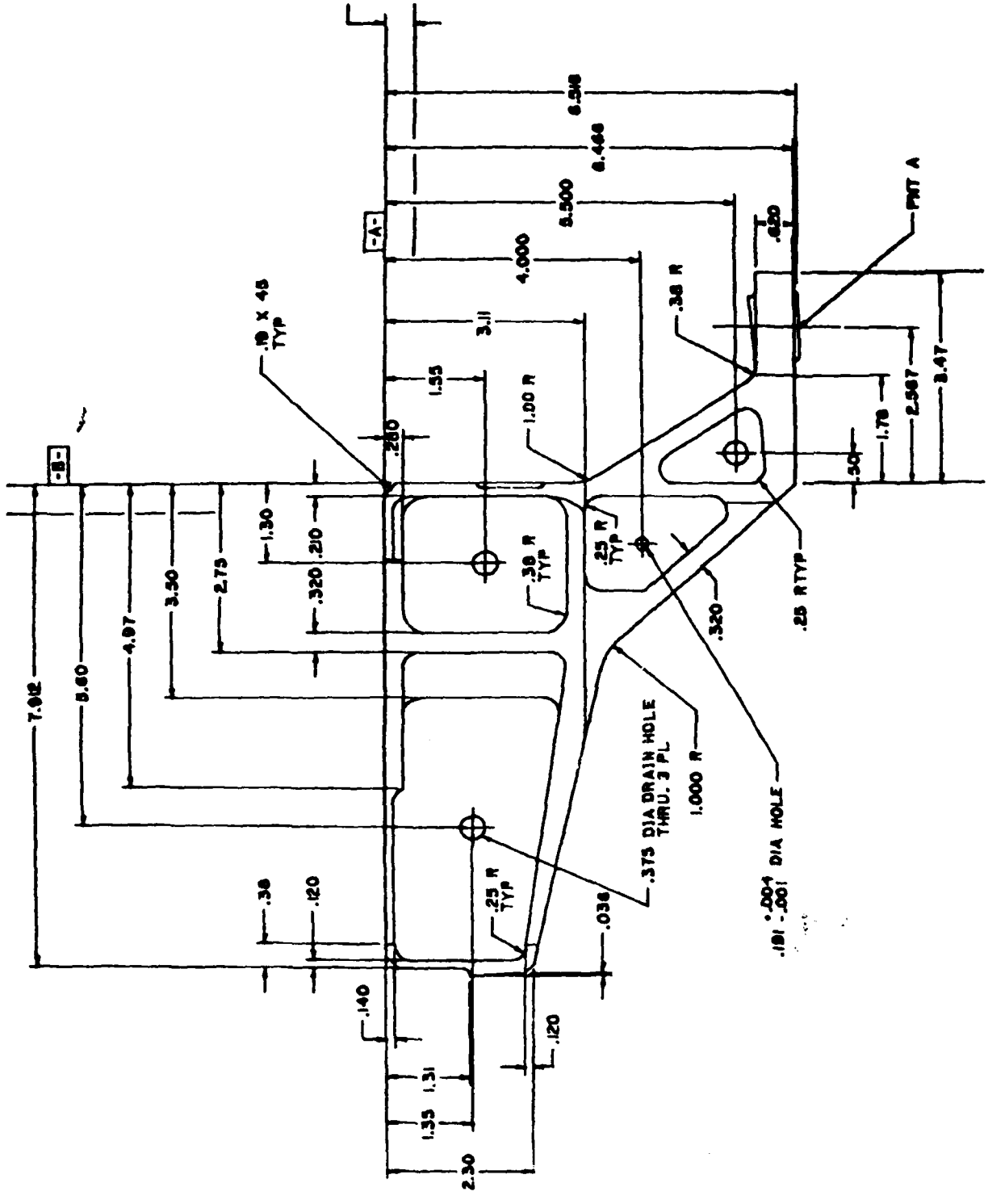
COMPUTER - GRAPHICS AUGMENTED DESIGN AND MANUFACTURING (CADAM)

- SOFTWARE PACKAGE DEVELOPED & MAINTAINED BY LOCKHEED
- MARKETED BY IBM
- ADDITIONAL IBM SUPPORT
  - NUMERICAL GEOMETRY SYSTEM (NGS) - ALLOWS 3D N/C CAPABILITY
  - SOFT COPY - PRODUCES RAPID COPIES OF SCREEN DISPLAYS
- RUNS ON MAINFRAME COMPUTER USING REFRESH GRAPHICS TERMINALS
- CONSIDERED TECHNICALLY ACCEPTABLE BY FRC PERSONNEL

CADAM INVESTIGATION AT FRC (1981)

- PILOT TEST PROGRAM AT FRC - 2 TERMINALS FOR 6 MONTHS
- STUDY TO BE COMPLETED (OCT 1981) PRIOR TO ACQUISITION OF ADDITIONAL HARDWARE





-A-
-B-
PNT A
.19 X 45 TYP
.38 R
1.00 R
.38 R TYP
.25 R TYP
.25 R TYP
.375 DIA DRAIN HOLE THRU. 3 PL
1.000 R
.191 +.004 -.001 DIA HOLE
6.516
6.466
5.500
4.000
3.11
1.55
.280
.620
3.47
2.567
1.78
.50
1.30
.210
.320
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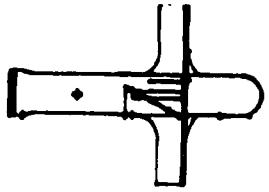
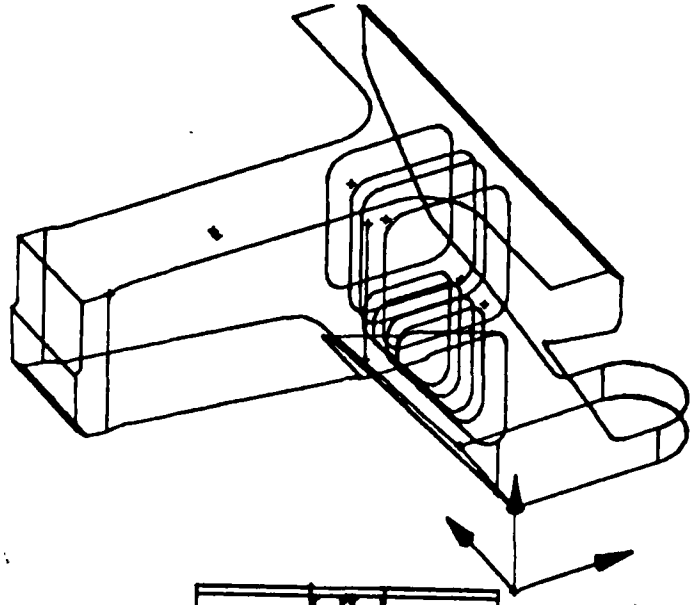
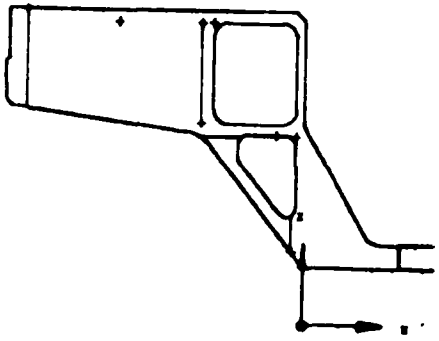
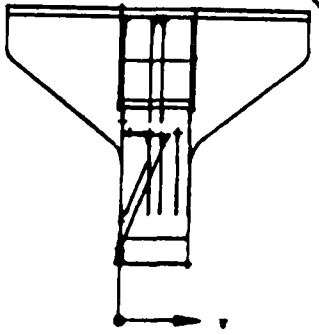
1.31
1.35
2.30



TOP



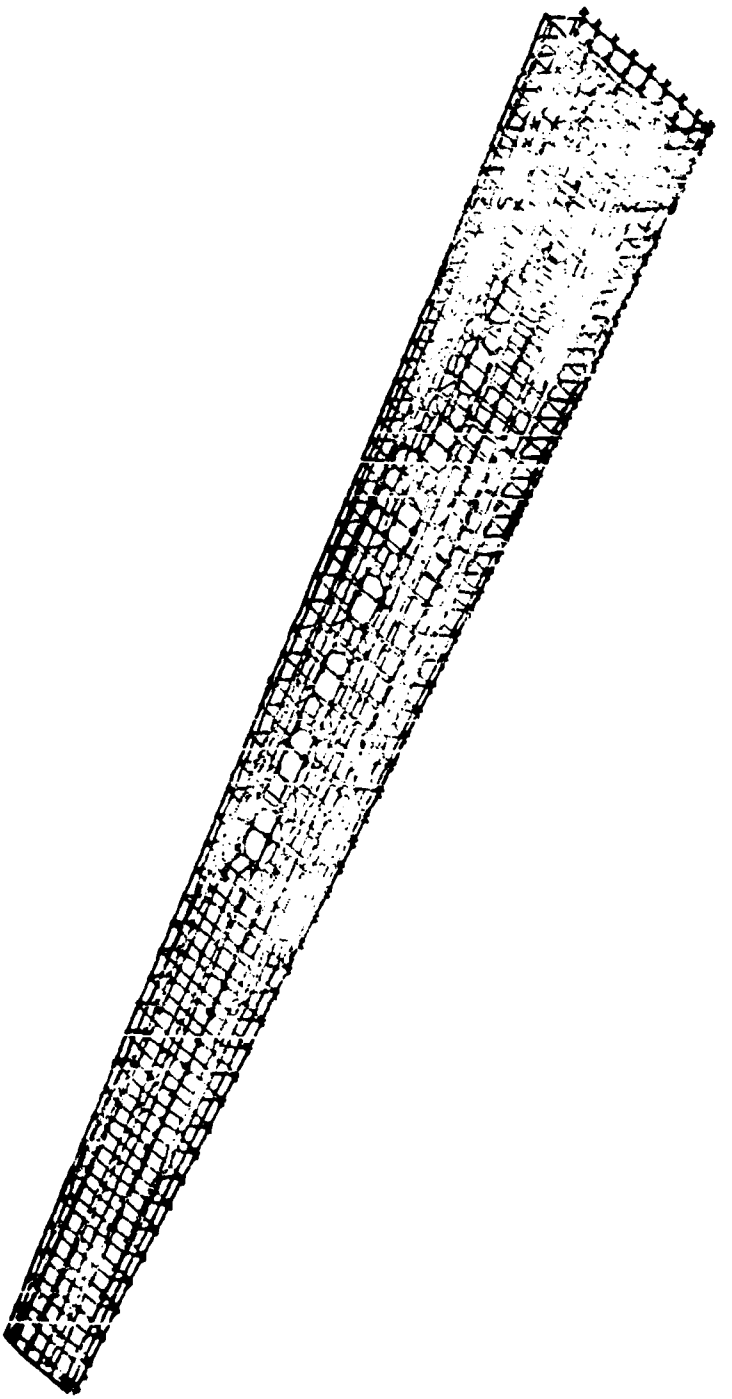


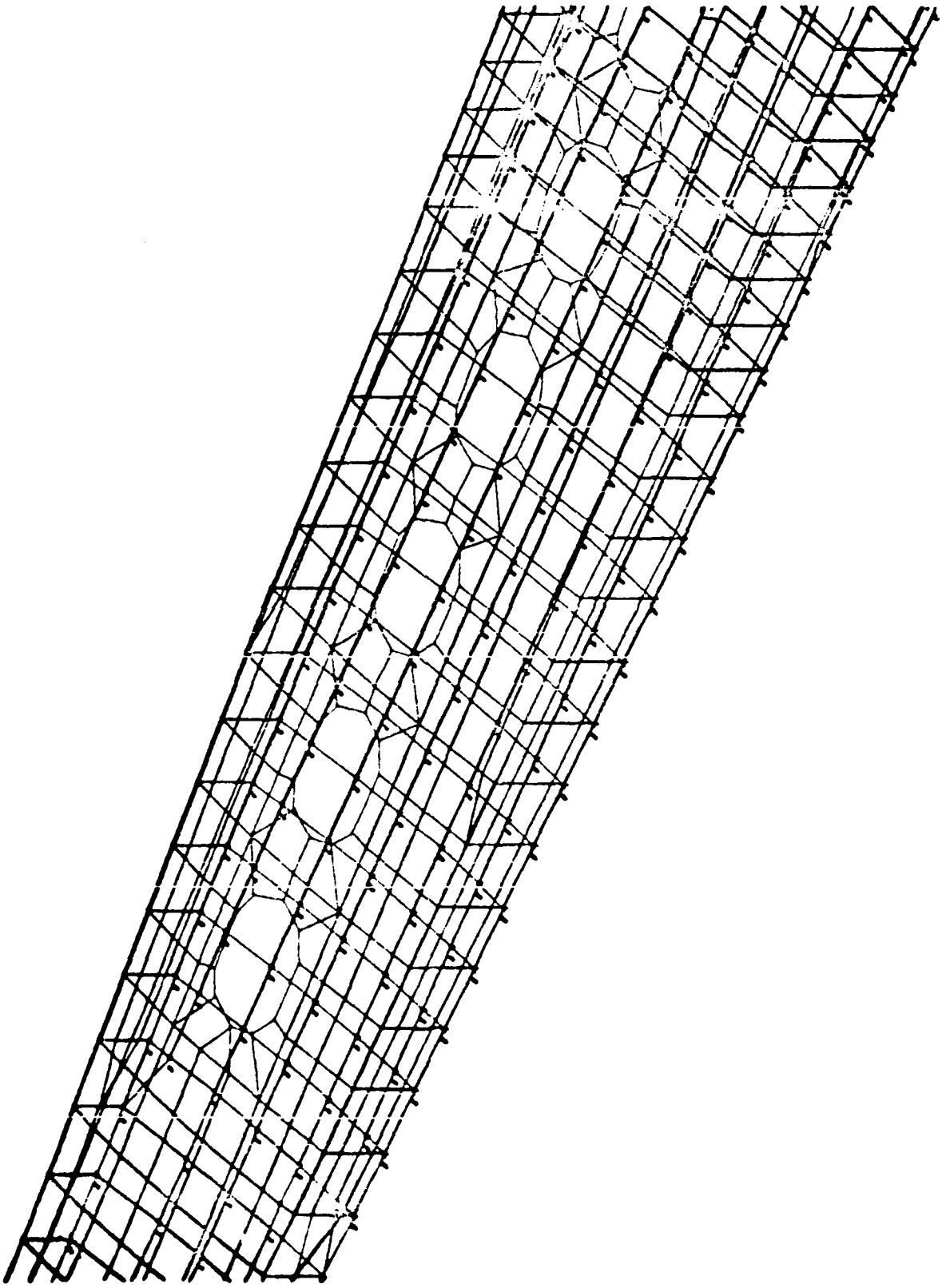


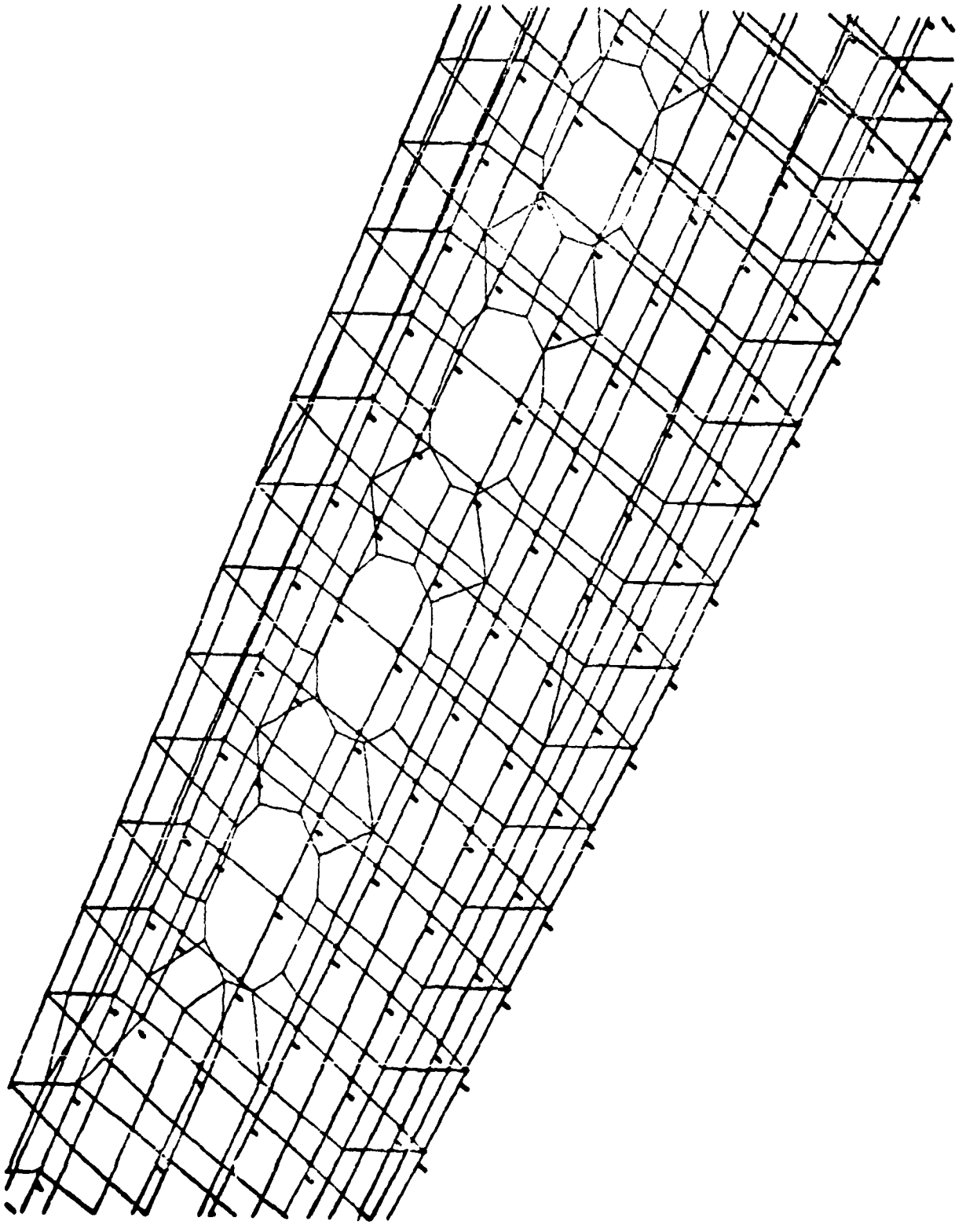
120

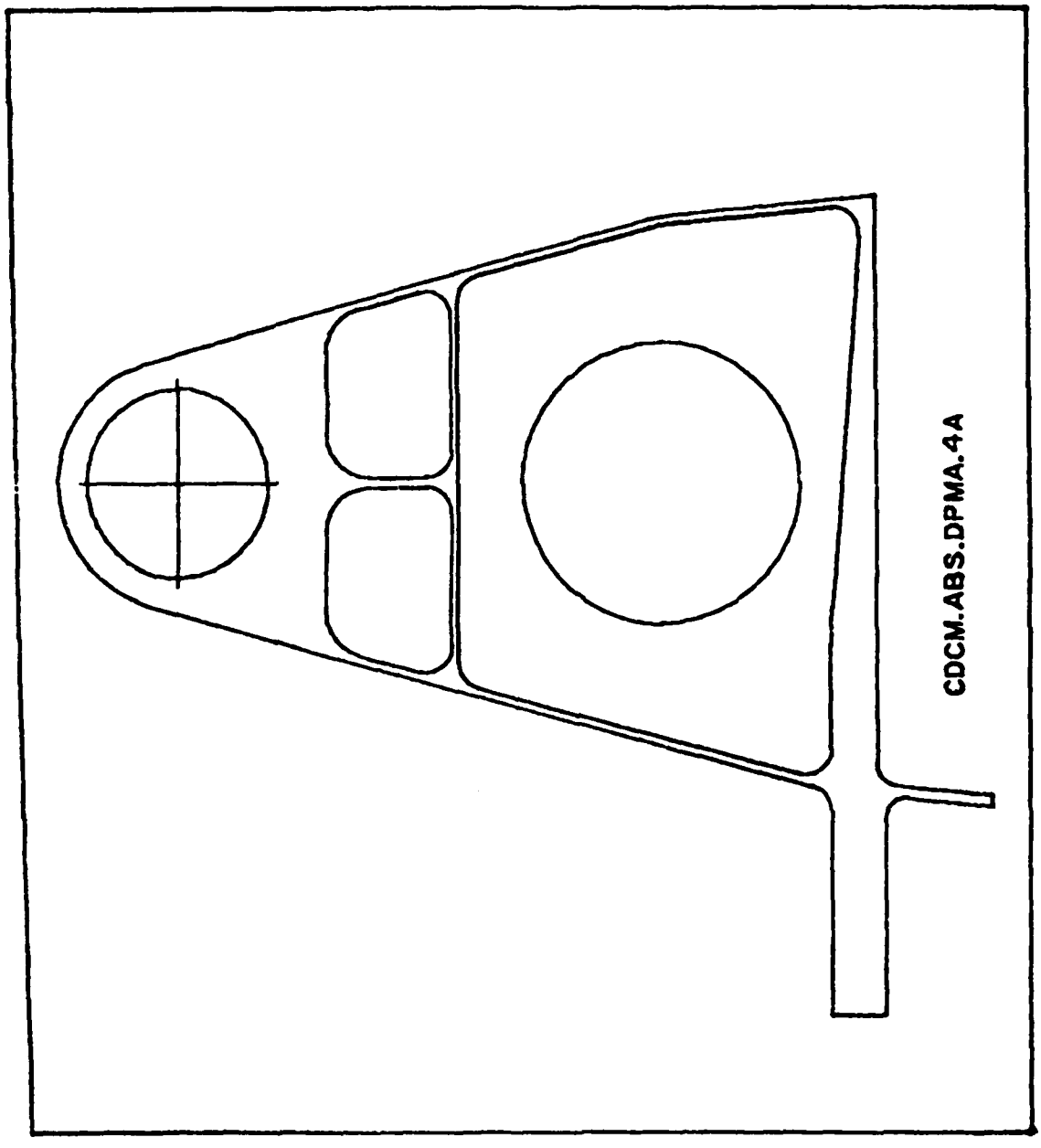
FRONT

RIGHT





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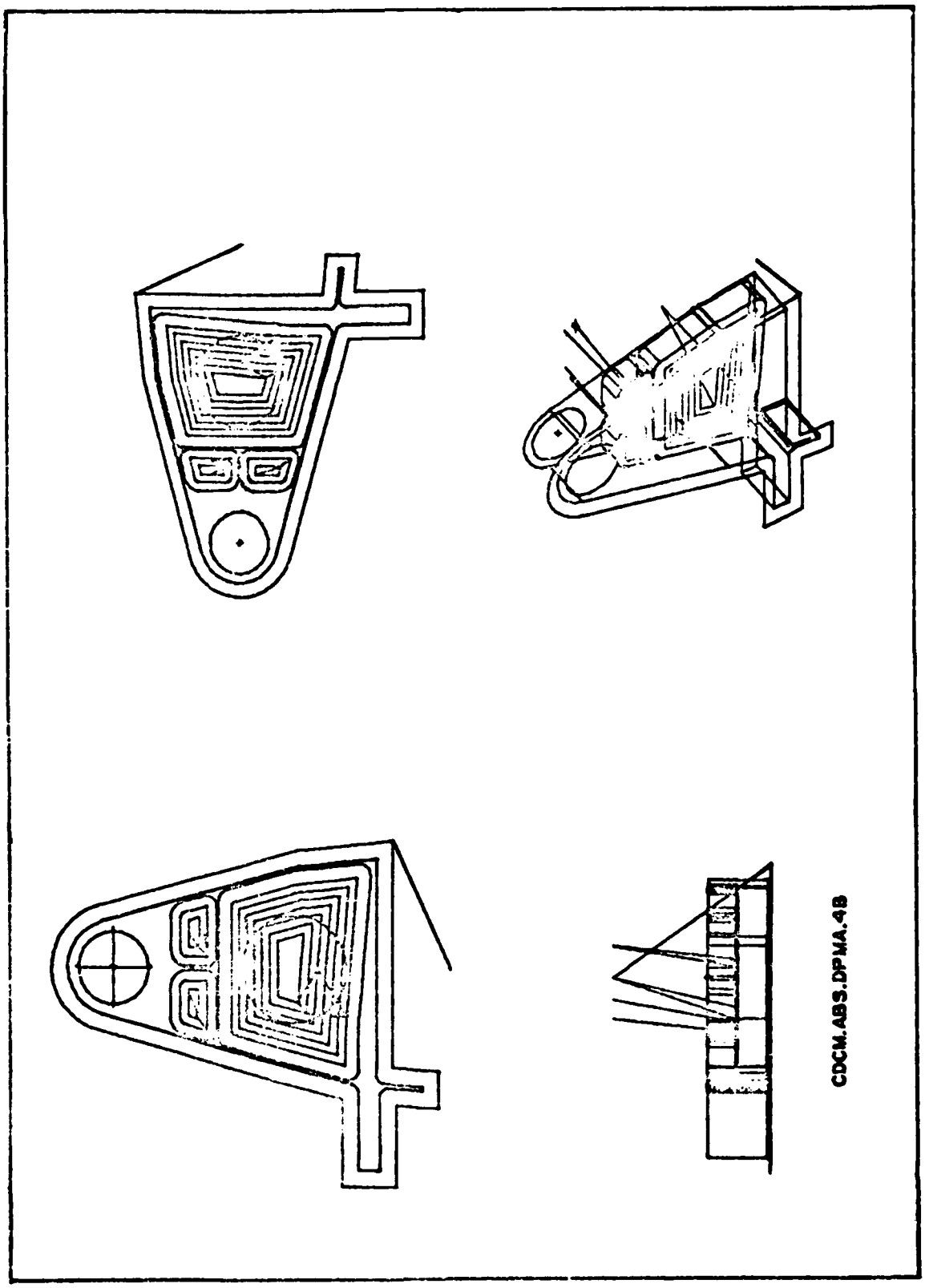
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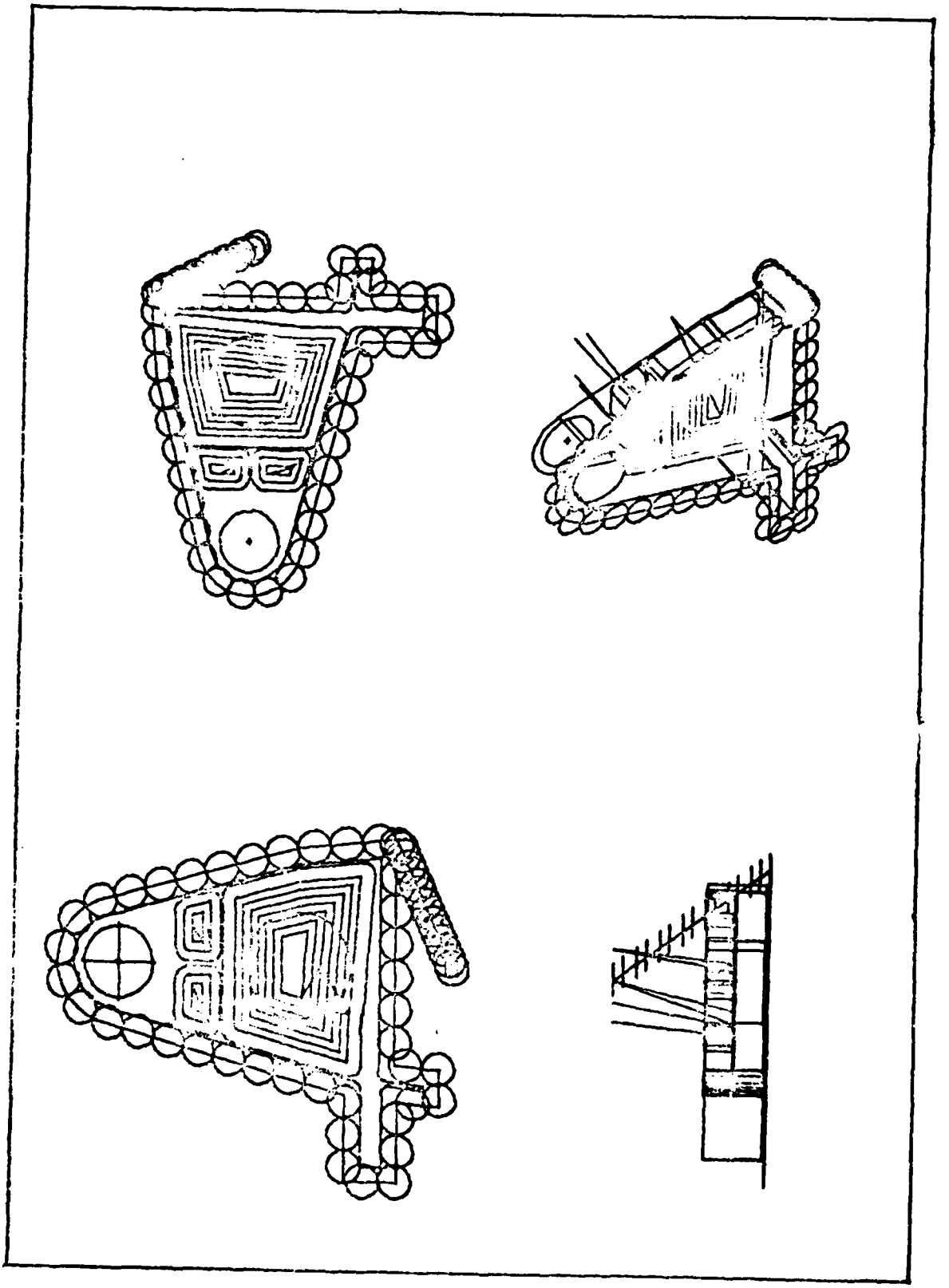


PRIME - DATA BASE SYSTEM DEVELOPMENT

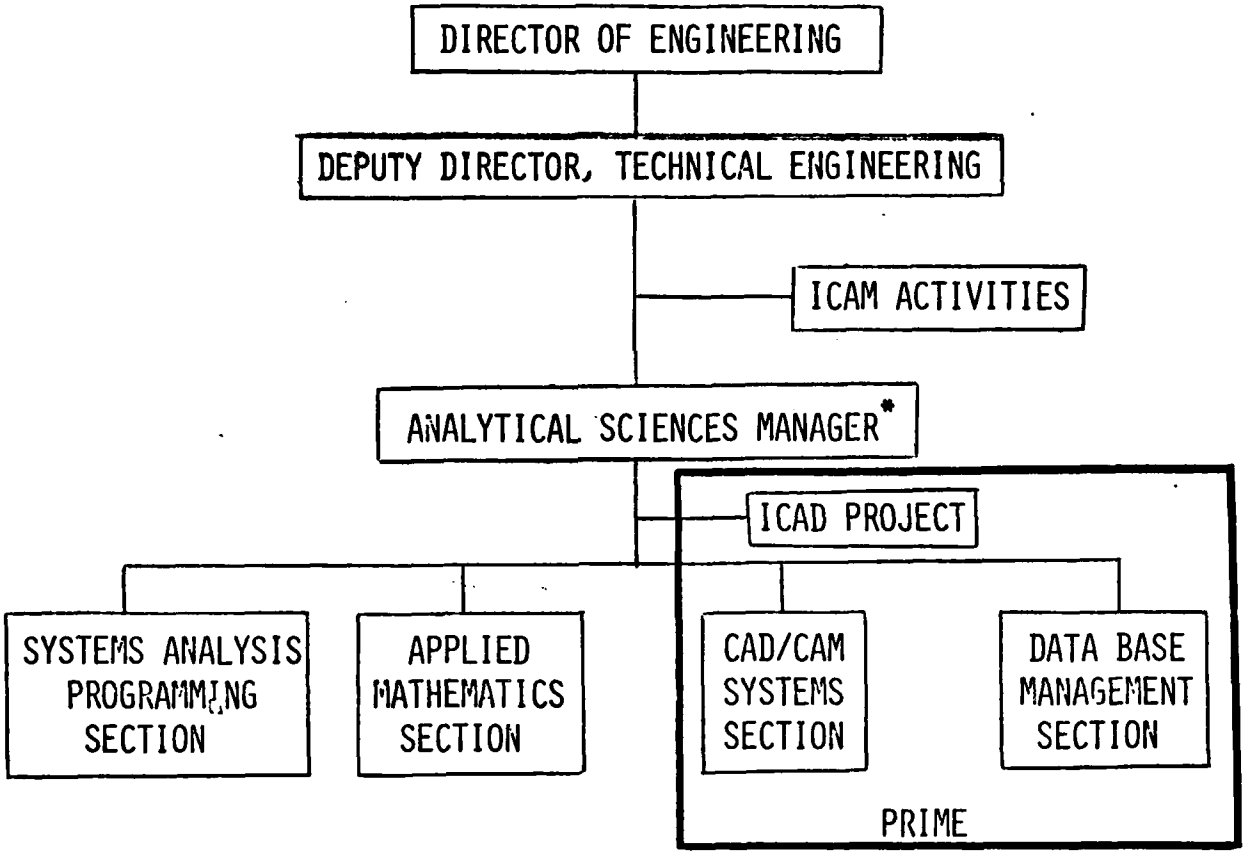
STATUS:

- ICAD FILE DIRECTORY SYSTEM DEVELOPED & IMPLEMENTED
  (INITIAL PRIME DATA MANAGEMENT CAPABILITY)
- REQUIREMENTS FOR COMPUTER PROGRAM CONTROL SYSTEM ESTABLISHED
- INVESTIGATION OF APPLICABILITY OF DATA BASE SYSTEMS FOR PRIME-ON-GOING

FUTURE PLANS:

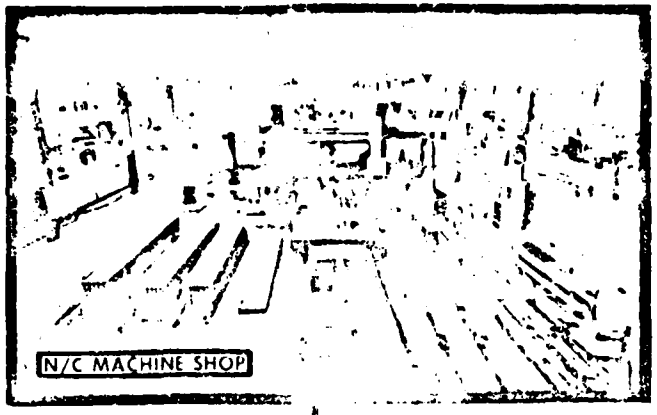
- IMPLEMENT COMPUTER PROGRAM CONTROL SYSTEM (1981)
- DEVELOPMENT OF ENGINEERING DATA DICTIONARY
- CONTINUE INVESTIGATION OF DATA BASE SYSTEMS FOR PRIME USE
- TEST & EVALUATE IPAD-DEVELOPED DATA BASE SYSTEM (RIM; IPIP)
- INSTALL AND IMPLEMENT DATA BASE MANAGEMENT SYSTEM FOR PRIME

PRIME IN THE STRUCTURE OF THE FRC ENGINEERING ORGANIZATION



* ALSO PRIME PROJECT MANAGER

THE ULTIMATE SYSTEM



DNC PROCESS COMPUTERS

HOST COMPUTER

DATA BASE

ENGINEERING

MANUFACTURING

A/C SIZING & TRADES

TECHNICAL ANALYSIS

DESIGN & DRAFTING

LOFTING

TEST DATA

NUMERICAL CONTROL

TOOLING

QUALITY ASSURANCE

PRODUCTION PLANNING

MATERIAL CONTROL

CAD AND ADVANCED COMPOSITE AIRCRAFT ELECTROMAGNETIC PROTECTION

John A Birken
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Washington, D.C.

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New materials, aircraft designs, and high-level threats are rapidly emerging which necessitate that future aircraft satisfy mission requirements from the onset of design. Mission requirements now include surviving increasing threats using low-level solid-state equipment, which comprise fly-by-wire control systems and composite materials that generally provide poor electromagnetic shielding. The need to know how each of the aircraft design disciplines interact upon each other has become essential. The Navy cannot afford to build aircraft, test them, and then correct for design defects not considered at the onset of the design. Furthermore, the ability to evaluate performance and cost impact from rapidly changing technologies and the change in military posture they necessitate has extremely high value.

These concepts give rise to the idea of using computer-aided technology in all aspects of aircraft design to arrive at a "total systems approach" to the optimization of aircraft design from structural, material, and electromagnetic viewpoints. This will avoid undue concentration on isolated aspects of the design, thereby producing greater total savings.

Two aircraft containing significant amounts of composite material, the YAV-8B and F-18 are shown in Figures 1 and 2. Other composite material platforms under development include the Advanced Attack Fighter, the MX missile, and the Advanced Composite Airframe Program (ACAP).

A general composite material can be defined as a manmade combination of two or more chemically distinct materials, with a distinct interface separating them, and created to obtain properties unachievable by the individual elements alone. Examples include graphite/epoxy, boron/epoxy, and Kelvar.

The increased use of composite materials in aircraft structures and subsystems significantly increases electromagnetic effects on avionics subsystems performance. The resulting avionics/computer failures jeopardize the pilot's life and the safety/mission of the aircraft, helicopter, or missile.

Cross-discipline issues to be considered in the use of composites are illustrated in Figure 3. For example, covering graphite/epoxy with aluminum foil can solve the electromagnetic shielding, lightning protection, water vapor absorption, and heating effects problems but not the corrosion, lifetime degradation, or maintenance and repair problems. Using a glass coating on graphite/epoxy with an aluminum facing, such as in Thorstrand material, solves the corrosion problem. However, the weight penalty may be too severe and the aluminum coating may not be thick enough or sufficiently conducting to provide electromagnetic protection. Some means of retarding lifetime degradation and good maintenance and repair must also be provided.

Similar interdiscipline concepts carry over into joint construction. To prevent corrosion, joints are bonded with nonconducting adhesive and anodized nonconducting fasteners, but this makes an electrically porous joint. For an electrically tight joint, conducting adhesive should be used together with fasteners that make good electrical contact.

Basic to an integrated approach is the design, control, and use of a common data base that reduces redundant efforts, assures validity of data, and shortens calendar time. This common data base is available in the NASA Structural Analysis Program (NASTRAN) geometric data base and other currently available computer-aided design programs used by the aircraft industry, such as in survivability/vulnerability studies for the F-14, shown in Figures 4 and 5. They have been extensively used in the design of the Navy F-18 aircraft and are currently being used in the AV-8B aircraft design. The geometrical data base available on the F-18 and AV-8B programs can be combined with existing electromagnetic analysis codes to evaluate the electromagnetic impact provided by new materials and structures. The results of the extensive electromagnetic testing of the F-18 and AV-8B provide an empirical basis to corroborate the integrated structural, material, and electromagnetic analysis codes with experiments already performed. NASTRAN or other CAD routines will serve as a means of communicating the structural material and electromagnetic properties of aircraft to the design engineer from inception of aircraft design.

The finite element model in Figure 6 is an example of an aircraft design using CAD techniques. The aft fuselage section is comprised of a non-conducting dielectric composite (Kelvar) with a protective layer of Thorstrand (developed by MB Associates). This section is presently

being tested at Sandia Laboratories with radiation from 10 kHz to 10 GHz in the test facility of Figure 7 and current injection from 1 kHz to 5 MHz. Previously, Kevlar panels with aluminum flame spray, wire grid mesh, Thorstrand, and silver paint were similarly tested using the box shown in Figure 8. It is shown using a triangular patch model in Figure 9.

To synthesize designs, the surface current J_s needs to be calculated as shown in Figure 10, which depicts a cross section of the General Dynamics F-16 graphite/epoxy non-aerodynamic forward fuselage. Here, we break the aircraft shape into finite sections and use the Method of Moments (MOM) or Finite Element Codes (FEC). Such capability is being exercised on the Naval Air Systems Command computer facility to evaluate electromagnetic performance of new aircraft designs and of significant existing aircraft modifications.

A MOM program based on triangular patch expansion functions is presently being implemented at the Naval Air Systems Command. Its output capabilities will include those shown in Figures 11 and 12. The results can be compared with the measured cases shown in Figures 13 and 14.

Figures 15 to 17 illustrate the electric shielding inside a two-dimensional graphite/epoxy F-16 forward fuselage. Figures 16 and 17 illustrate the effect of a window. A number of cases were run illustrating that: (a) for the TM case (E_z parallel to z), as frequency is lowered, the effect of the window on degradation of shielding is minimized, (b) the effect of a window on the TE case (H_z parallel to z) drastically reduces shielding effectiveness, and (c) TE shielding was virtually nil below 10 kHz.

To synthesize the electromagnetic protection required by advanced composite material aircraft, helicopters, and missiles, it is necessary to generate the transfer functions D(f) and $T_1(f)$ through $T_5(f)$ of Figure 18 for different airframes and avionic systems. Knowledge of D(f) and $T_1(f)$ through $T_5(f)$ allow evaluation of voltages and currents which result from the different threats.

The frequency spectrum for nuclear, lightning, and projected laser threats is shown in Figure 19. This chart shows the high intensity of lightning at low frequencies and that the nuclear pulse has a higher frequency content.

Graphite/epoxy is the best conducting composite material with a conductivity of 10^4 mhos/m, while Kelvar is a nonconducting dielectric composite material with a conductivity of 6×10^{-9} mhos/m. A measure of material shielding is given by the term transfer impedance, given for all frequencies by

$$Z_{st} = E_t/J_s = \eta \operatorname{csch}(\gamma d) \qquad (1)$$

where $\eta = j\omega\mu/\sigma$ is the intrinsic impedance of the shield, $\gamma = j\omega\mu\sigma$ is the propogation factor, and d is the shield thickness. Figure 20 shows the surface transfer impedance for aluminum graphite/epoxy, and boron/epoxy in the same thickness as 8-ply graphite/epoxy (0.001069 m). Figure 21 plots the low frequency asymptote of $T_1(f)$ in bar chart form. The figure illustrates the shielding effectiveness of the various foils, on an absolute scale including an 8-ply laminate of graphite/epoxy. Figure 20 illustrates the improvement in transfer impedance as frequency increases. Designs with the number from Figure 21 reflect requirements imposed by the very low frequency content of lightning and the nuclear pulse.

Figures 22 through 27 are descriptions of some of the remaining transfer functions, $T_2(f)$ through $T_5(f)$.

Predicted values of voltage and current resulting from full-thrust lightning and nuclear pulses on an all composite aircraft are shown in Figure 28. These scale remarkably well with measured values gathered to date.

Figure 29 shows the improvement of various protective coatings on 8-ply graphite/epoxy. The plot is on an absolute scale with all coating thicknesses fixed at 4 mils. For the coatings considered, the effect of the coatings dominates the shielding of the graphite/epoxy.

The improvement that protective coatings provide relative to 8-ply graphite/epoxy is just the ratio of their transfer impedance, or

$$\text{Improvement} = \frac{V(G/E)}{V(\text{coating})} = \frac{Z_{st}(G/E)}{Z_{st}(\text{coating})} = \frac{1/\sigma_{G/E}d_{G/E}}{1/\sigma_c d_c} = \frac{\sigma_c d_c}{\sigma_{G/E}d_{G/E}} \qquad (2)$$

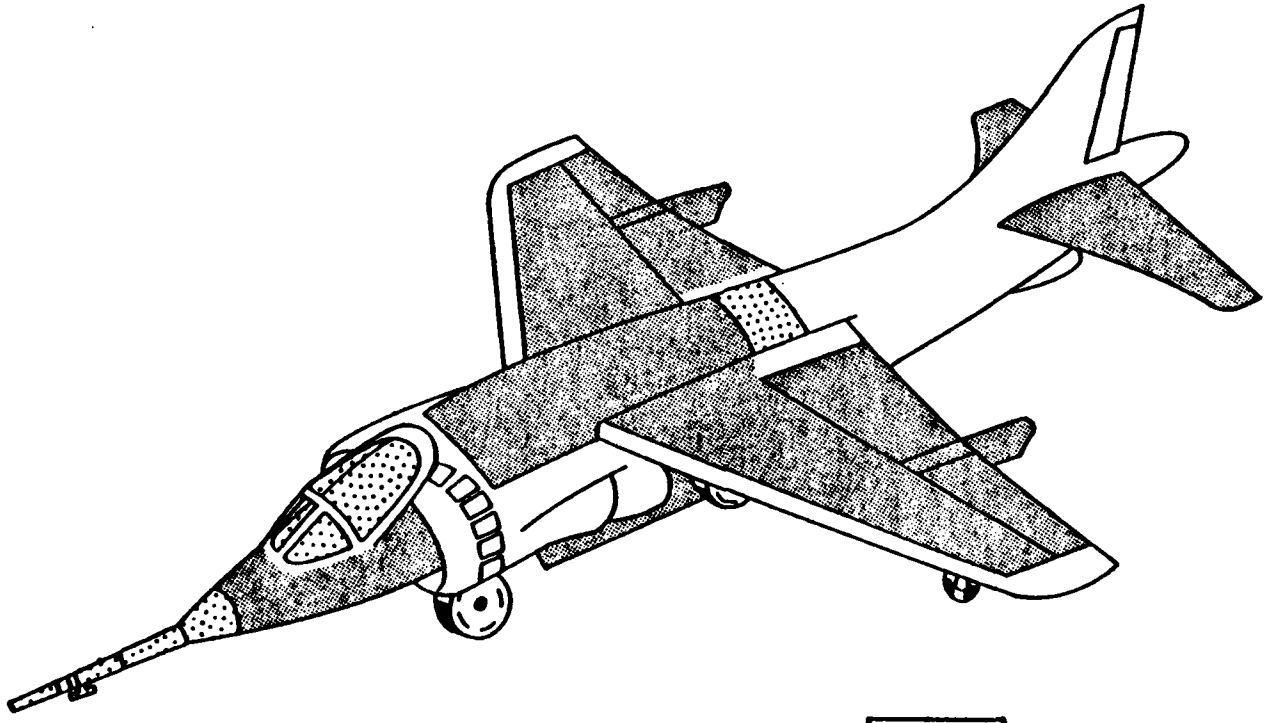
A non-conducting layer between the conducting coating and graphite/epoxy is assumed to prevent corrosion.

The weight penalty paid by coating with 4 mils of various foil meshes and flame spray in shown in Figure 30. This is based on 100 ft^2 of coating, which is the estimated surface area of the AV-8B graphite/epoxy forward fuselage.

The combined measure of shielding and weight penalty for the various coatings is given in Figure 31. It is defined as

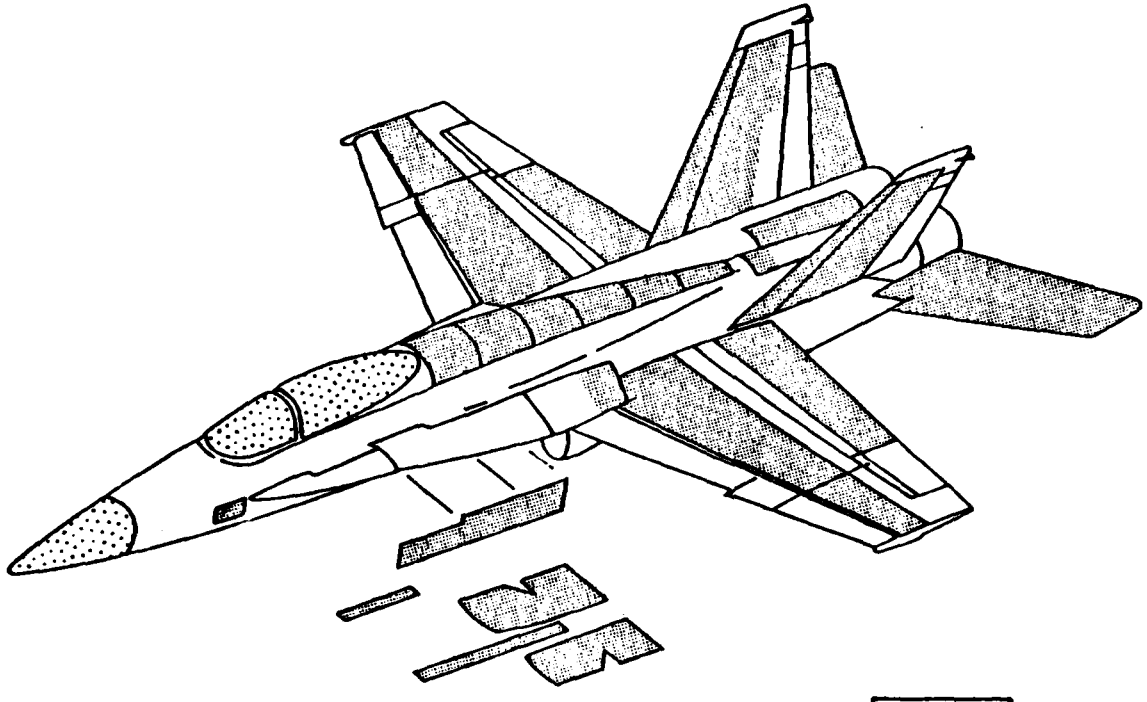
$$\text{Figure of Merit} = \frac{\text{Improvement}}{\text{Surface Density}} \tag{3}$$

$$= \frac{Z_{st}(G/E)/Z_{st}(\text{coating})}{\rho_s}$$



	Structural Weight
Aluminum	50%
Graphite/Epoxy	20%
Other	30%

Figure 1. YAV-8B Composites Applications



	Structural Weight
Aluminum	50%
Graphite/Epoxy	10%
Other	40%

Figure 2. F-18 Composites Application

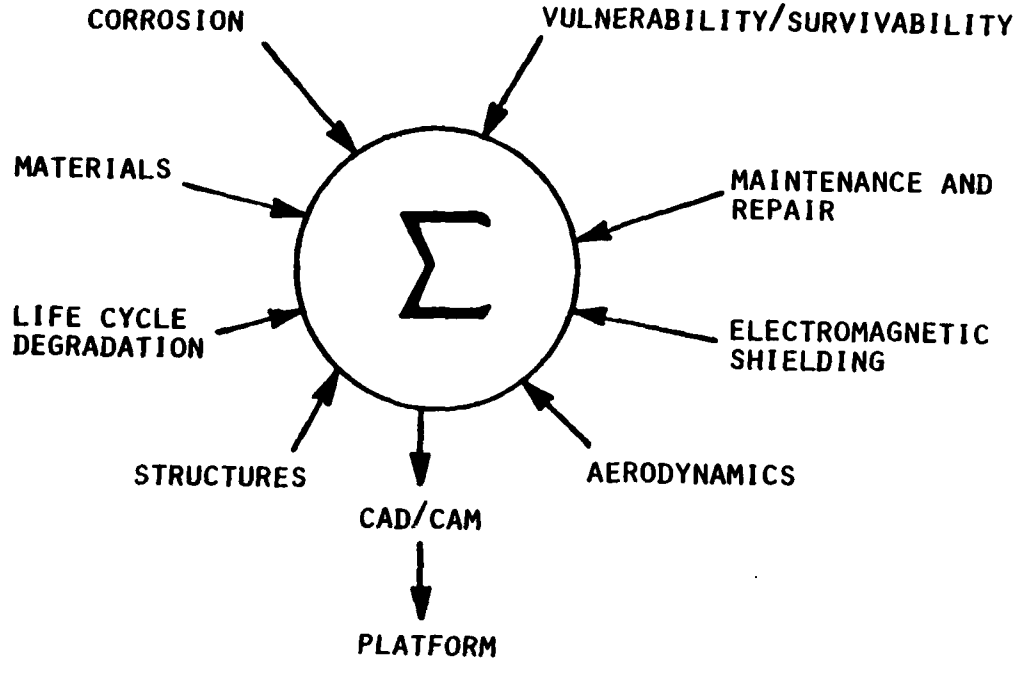


Figure 3. Synergize Platform Disciplines

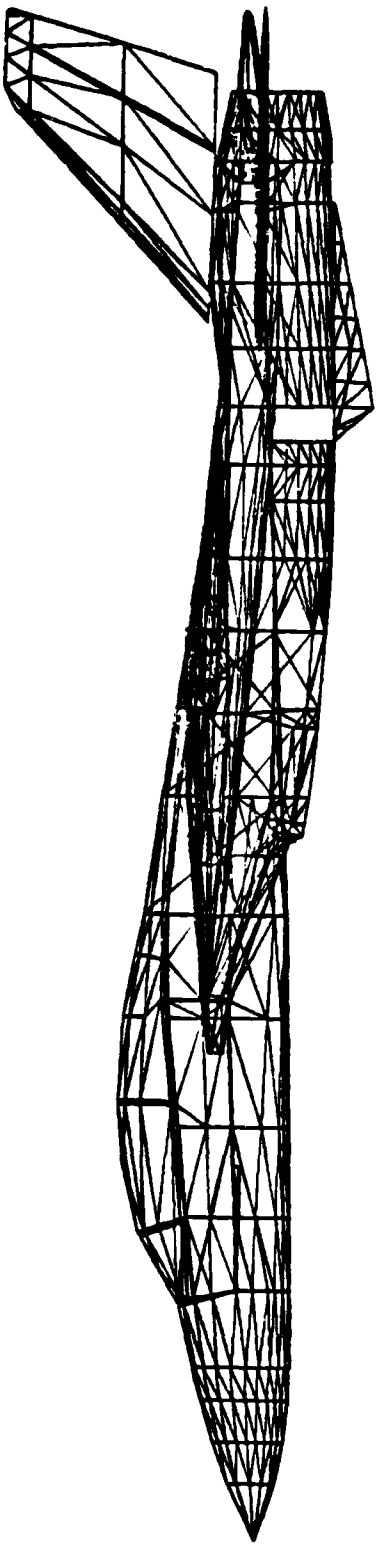


Figure 4. F-14 Survivability/Vulnerability Model

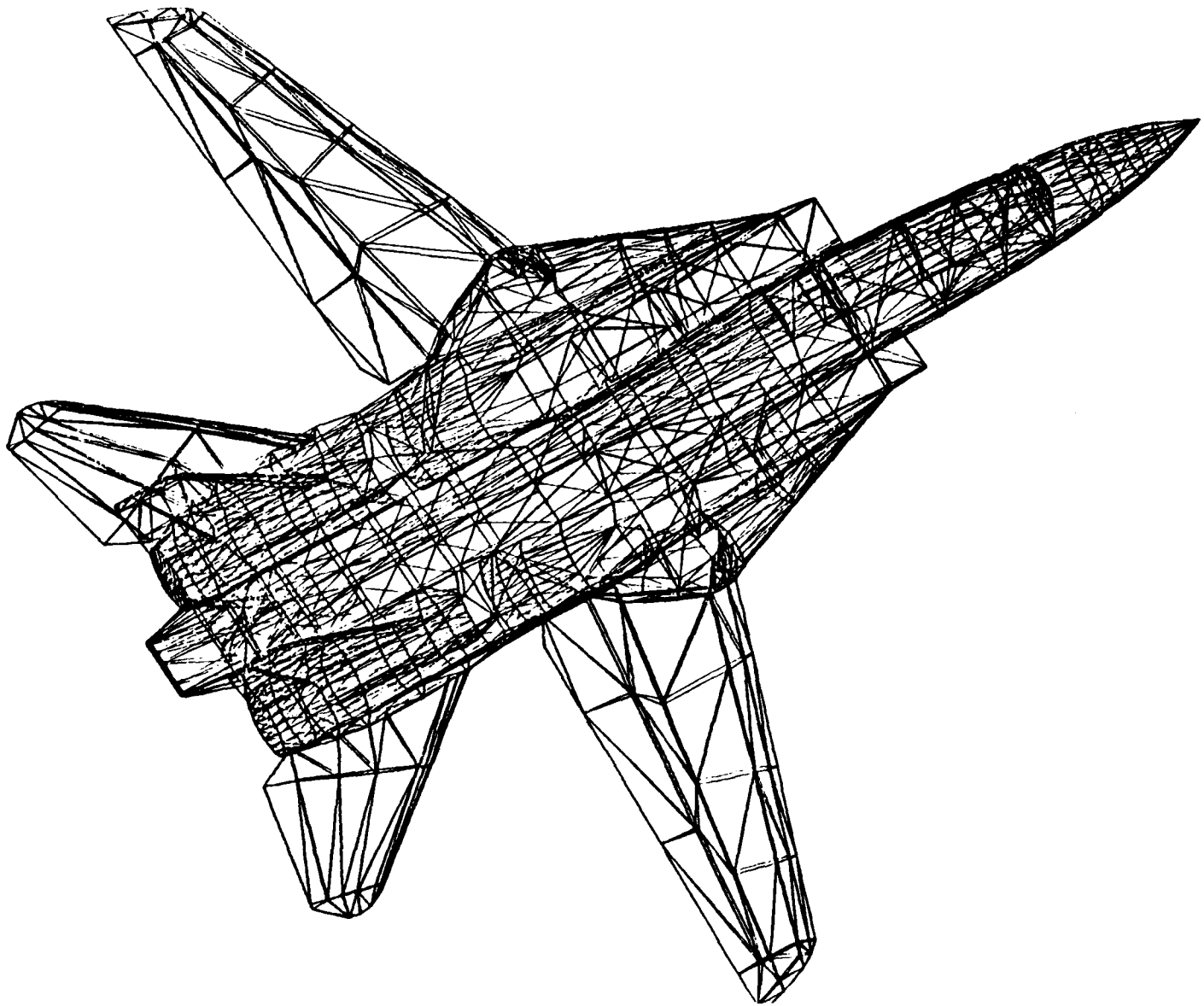


Figure 5. F-14 Survivability/Vulnerability Model

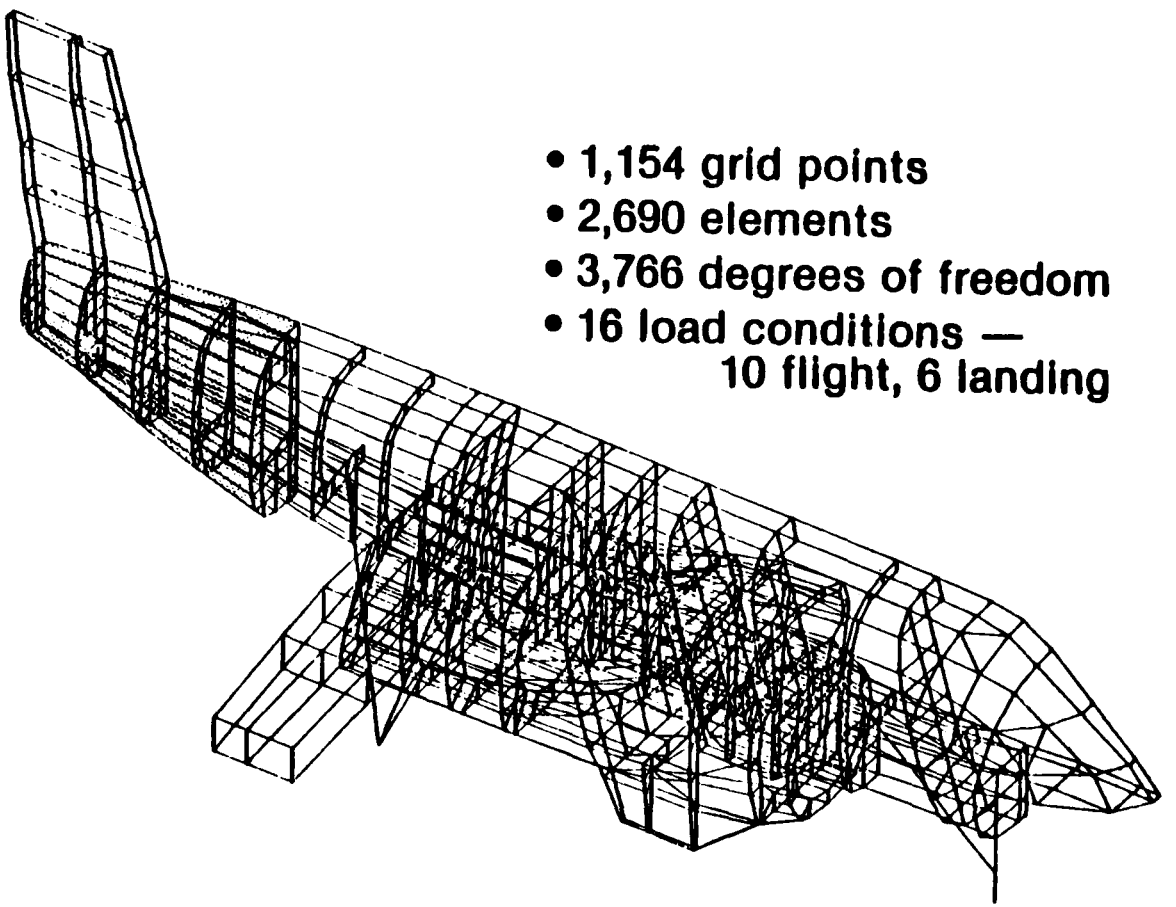


Figure 6. Kevlar Aft Fuselage Section

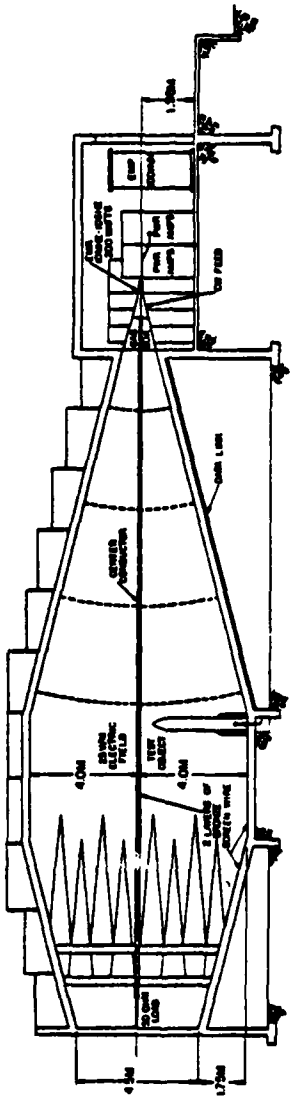


Figure 7. Side View EMES

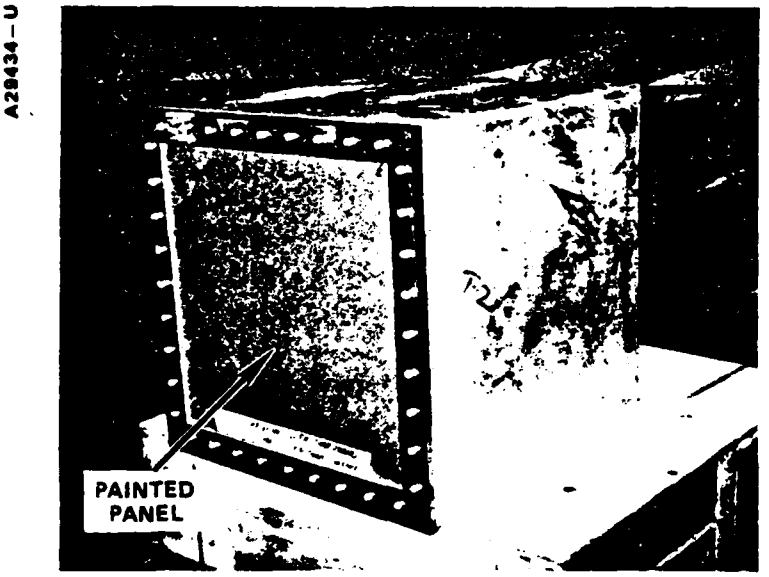


Figure 8. View of Welded Aluminum Box with Kevlar-Thorstrand-Silver Painted Panel Mounted for Test

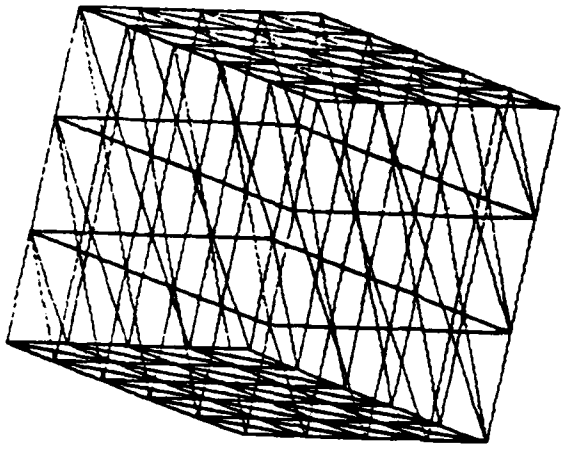


Figure 9. Triangulated Box

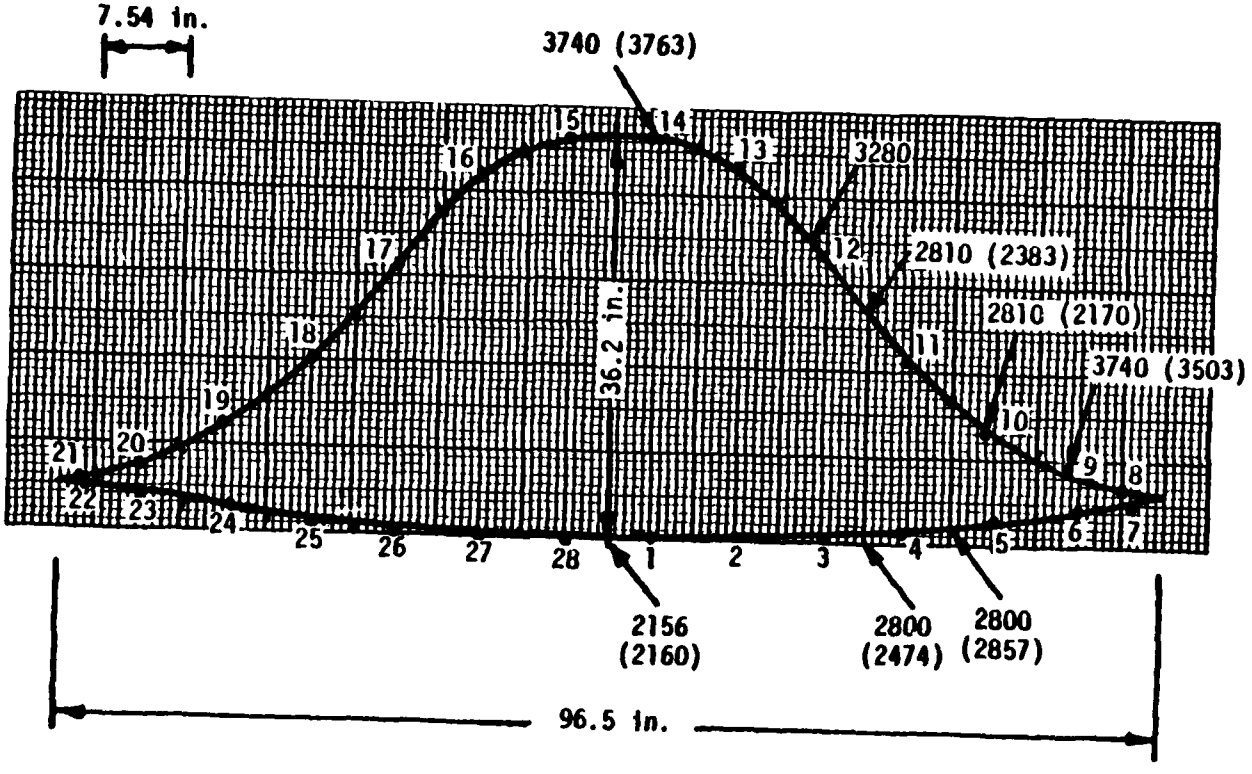


Figure 10. Free-Space Logitudinal Current Distribution on Conducting Cylindrical Contour, I_{total} = 20 kA

- SURFACE CURRENT DENSITY ON MIXED MATERIAL PLATFORM
- TRANSFER IMPEDANCE - $Z_{st}(f,\sigma,d)$
- JOINT ADMITTANCE - $Y_j(f,\sigma,d,w)$
- MAGNETIC AND ELECTRIC SHIELDING $S_{H,E}(Z_{st}F,V/S)$
- MAGNETIC AND ELECTRIC FIELDS
  - EXTERNAL
  - INTERNAL
  - SPATIAL DISTRIBUTION
  - RADAR CROSS SECTION (RCS)
- OPEN-CIRCUIT VOLTAGES AND SHORT-CIRCUIT CURRENT

Figure 11. Output Capabilities

TRIANGULAR PATCH MODELLING OF A THREE-DIMENSIONAL SHELL STRUCTURE COMPOSED OF COMPOSITE MATERIAL PANELS

ASSUMPTIONS

- SURFACE OF BODY MAY BE MODELLED BY A MESH OF TRIANGULAR PATCHES
- EACH PATCH HAS AN EFFECTIVE THICKNESS d WHERE $d << \lambda_0$
- EACH PATCH HAS AN EFFECTIVE BULK CONDUCTIVITY σ AND RELATIVE DIELECTRIC CONSTANT ε_r

ADVANTAGES

- ABILITY TO MODEL AN ARBITRARY SURFACE GEOMETRY ACCURATELY
- GIVES EXCELLENT REPRESENTATION OF SURFACE CURRENTS AND CHARGE DENSITIES WHICH ARE NEEDED FOR SMALL APERTURE AND JOINT COUPLING FORMULATIONS
- BETTER INTERIOR FIELD COMPUTATIONS THAN ACHIEVED WITH WIRE-GRID OR OTHER NON-SURFACE PATCH TECHNIQUES

DISADVANTAGES

- MATRIX SIZE INCREASES VERY RAPIDLY WITH BODY ELECTRICAL SIZE AND/OR GEOMETRICAL COMPLEXITY

Figure 12. Output Capabilities

- F-14; MIXED ALUMINUM AND GRAPHITE/EPOXY
- F-16
- BOX - KEVLAR, KEVLAR WITH PROTECTIVE COATING
- V/STOL - KEVLAR WITH THORSTRAND

Figure 13. Cases Considered

- F-16 MOCKUP; GRAPHITE/EPOXY FORWARD FUSELAGE
- HAWKER
- BOX
- V/STOL AFT FUSELAGE
- MX CANNISTER

Figure 14. Cases Measured

PLOT OF 20 $\log|H_z^{ext}/H_z^{int}|$ AT POINTS INSIDE SHELL.

THICKNESS = 1 mm (7.5 plies)
CONDUCTIVITY = 10^4 mhos/m
FREQUENCY = 10 MHz

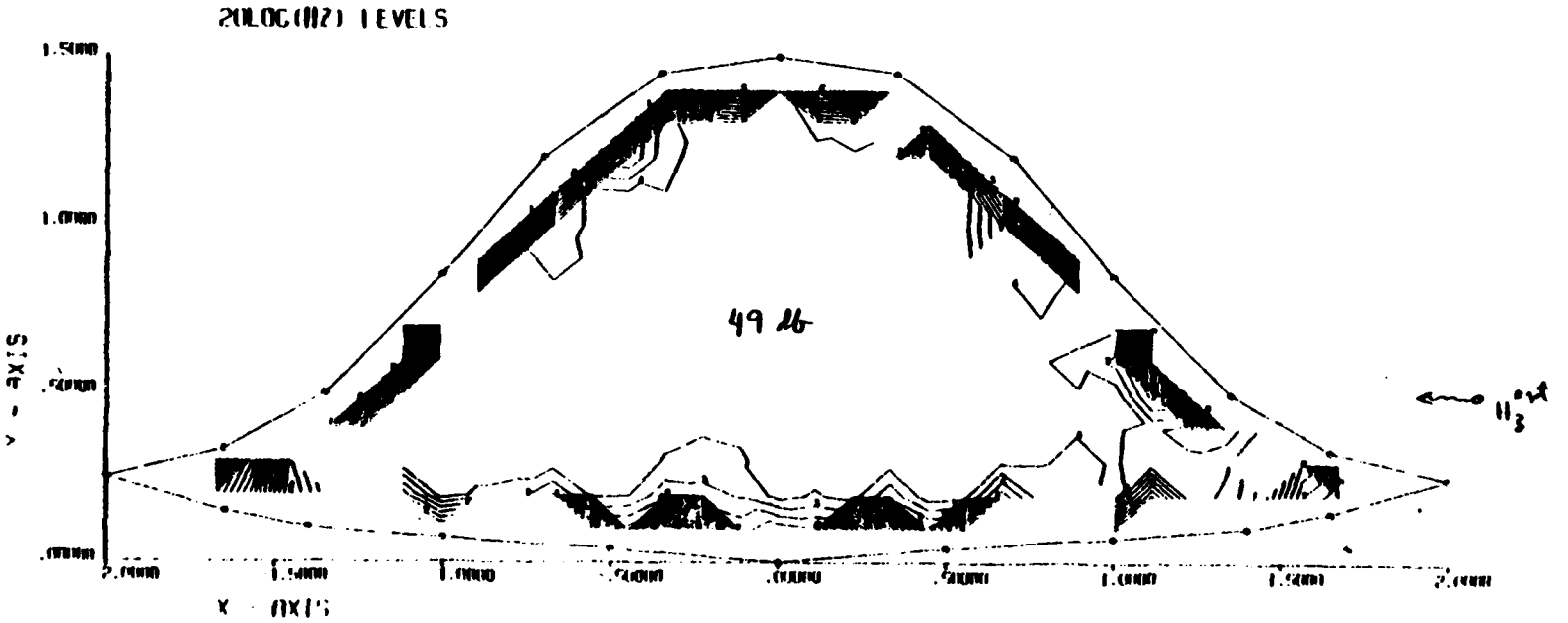


Figure 15. Electric Shielding Inside a Two-Dimensional Graphite/Epoxy F-16 Forward Fuselage

PLOT OF 20 $\log|E_z^{ext}/E_z^{int}|$ AT POINTS

INSIDE SHELL.

THICKNESS = 1 mm (7.5 plies)

CONDUCTIVITY = 10^4 mhos/m except where noted

FREQUENCY = 0.1 MHz

CONTOUR PLOT * PLOTTED LEVELS

CONTOUR LEVEL	32.500	LABELED BY A
CONTOUR LEVEL	33.000	LABELED BY B
CONTOUR LEVEL	33.500	LABELED BY C
CONTOUR LEVEL	34.000	LABELED BY D
CONTOUR LEVEL	34.500	LABELED BY E
CONTOUR LEVEL	35.000	LABELED BY F
CONTOUR LEVEL	35.500	LABELED BY G
CONTOUR LEVEL	36.000	LABELED BY H
CONTOUR LEVEL	36.500	LABELED BY I
CONTOUR LEVEL	37.000	LABELED BY J
CONTOUR LEVEL	37.500	LABELED BY K
CONTOUR LEVEL	38.000	LABELED BY L
CONTOUR LEVEL	38.500	LABELED BY M
CONTOUR LEVEL	39.000	LABELED BY N
CONTOUR LEVEL	39.500	LABELED BY O
CONTOUR LEVEL	40.000	LABELED BY P
CONTOUR LEVEL	40.500	LABELED BY Q

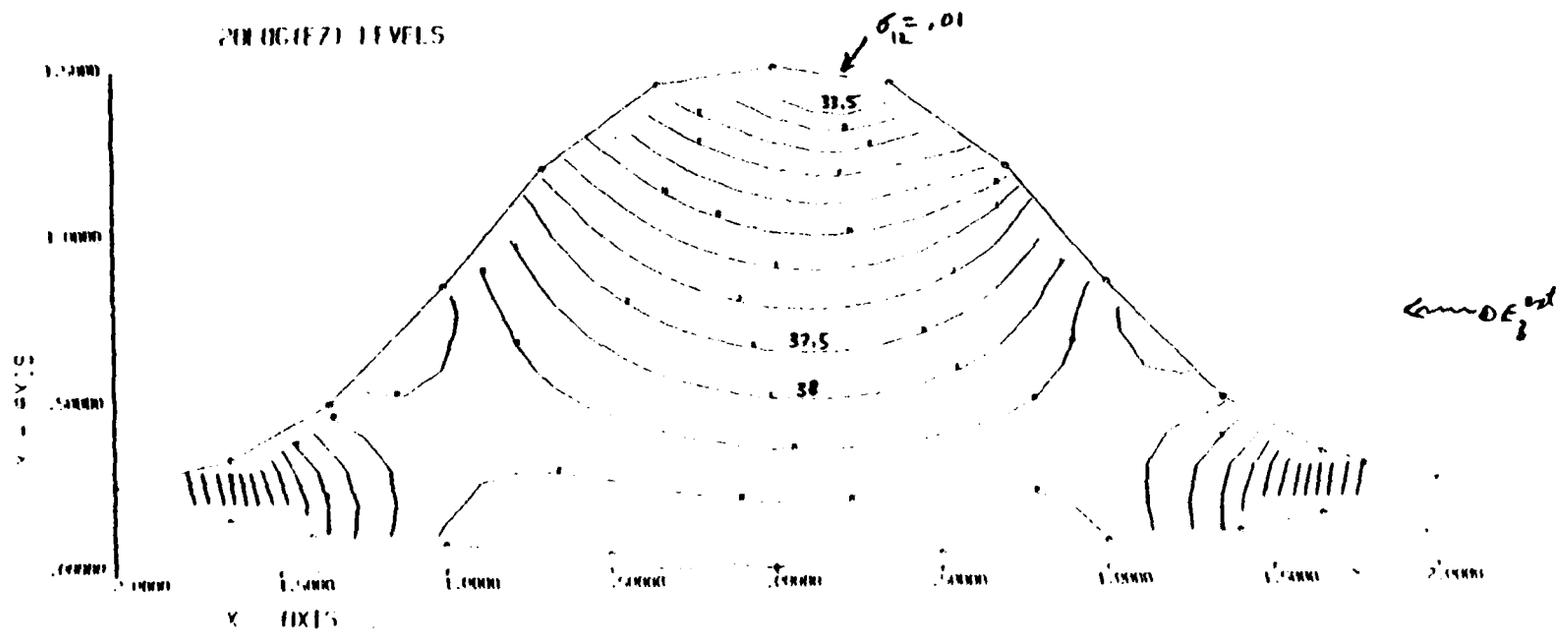


Figure 16. Electric Shielding Inside a Two-Dimensional Graphite/Epoxy F-16 Forward Fuselage with the Effect of a Window

PLOT OF 20 $\log|E_z^{ext}/E_z^{int}|$ AT POINTS INSIDE SHELL.

THICKNESS = 1 mm (7.5 plies)

CONDUCTIVITY = 10^4 mhos/m except where noted

FREQUENCY = 10 MHz

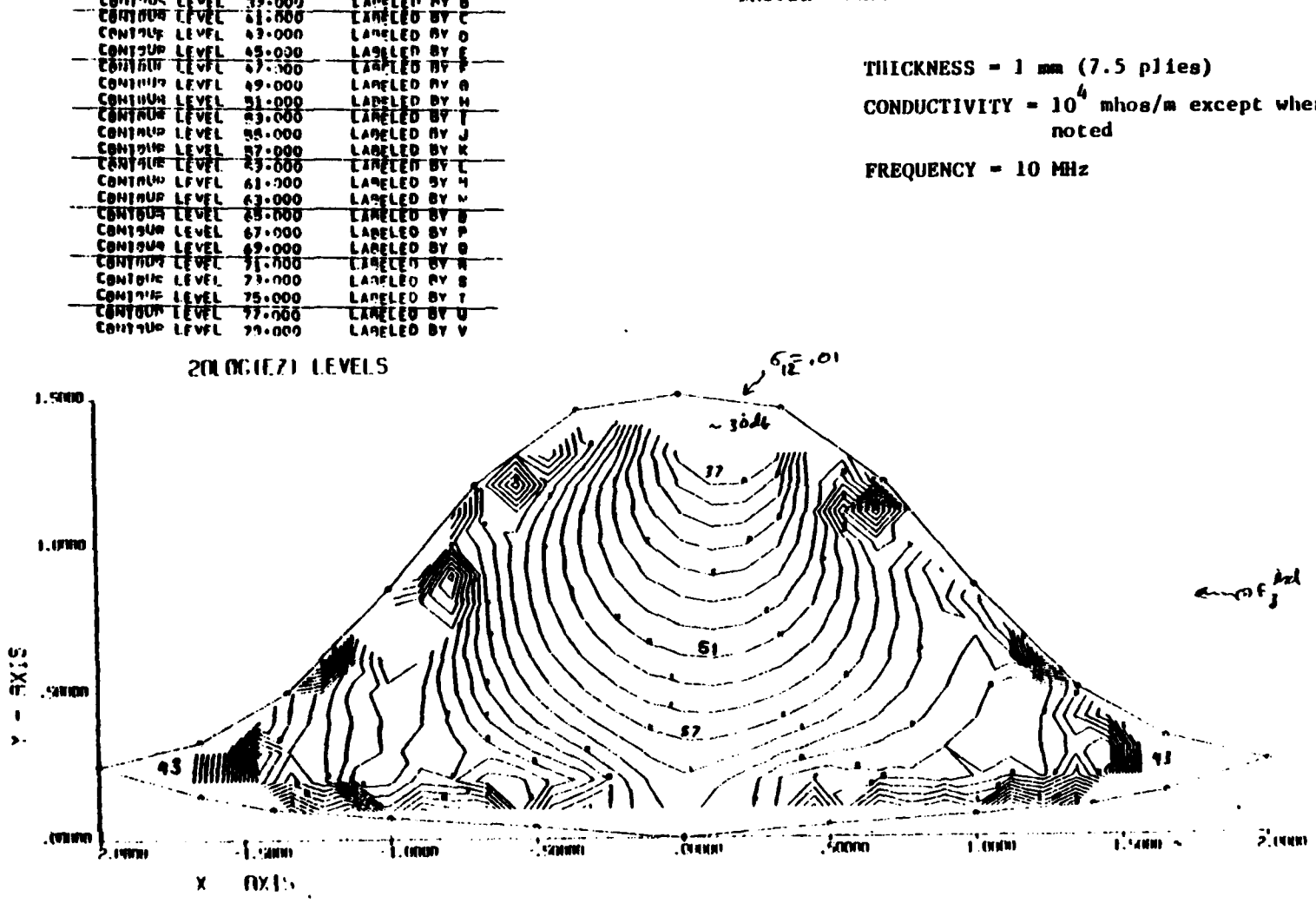


Figure 17. Electric Shielding Inside a Two-Dimensional Graphite/Epoxy F-16 Forward Fuselage with the Effect of a Window

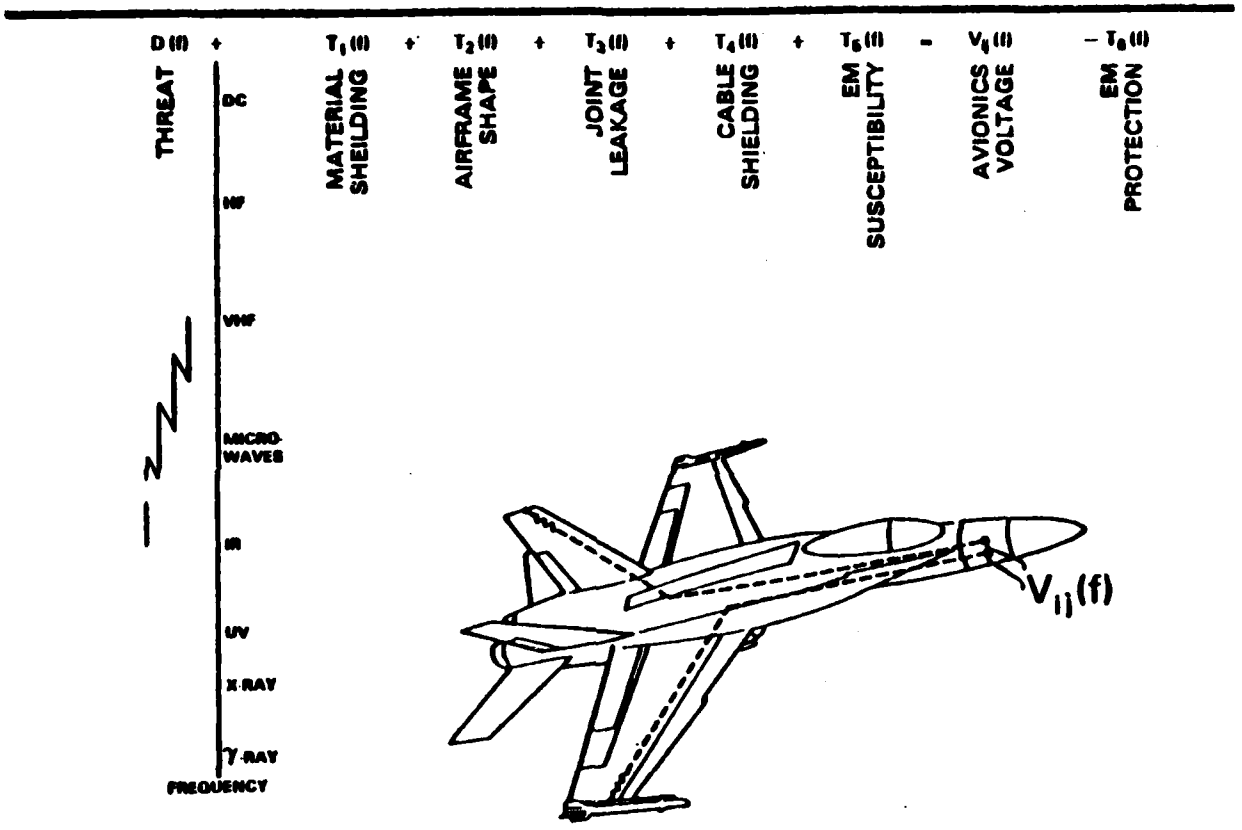


Figure 18. Electromagnetic System Parameters

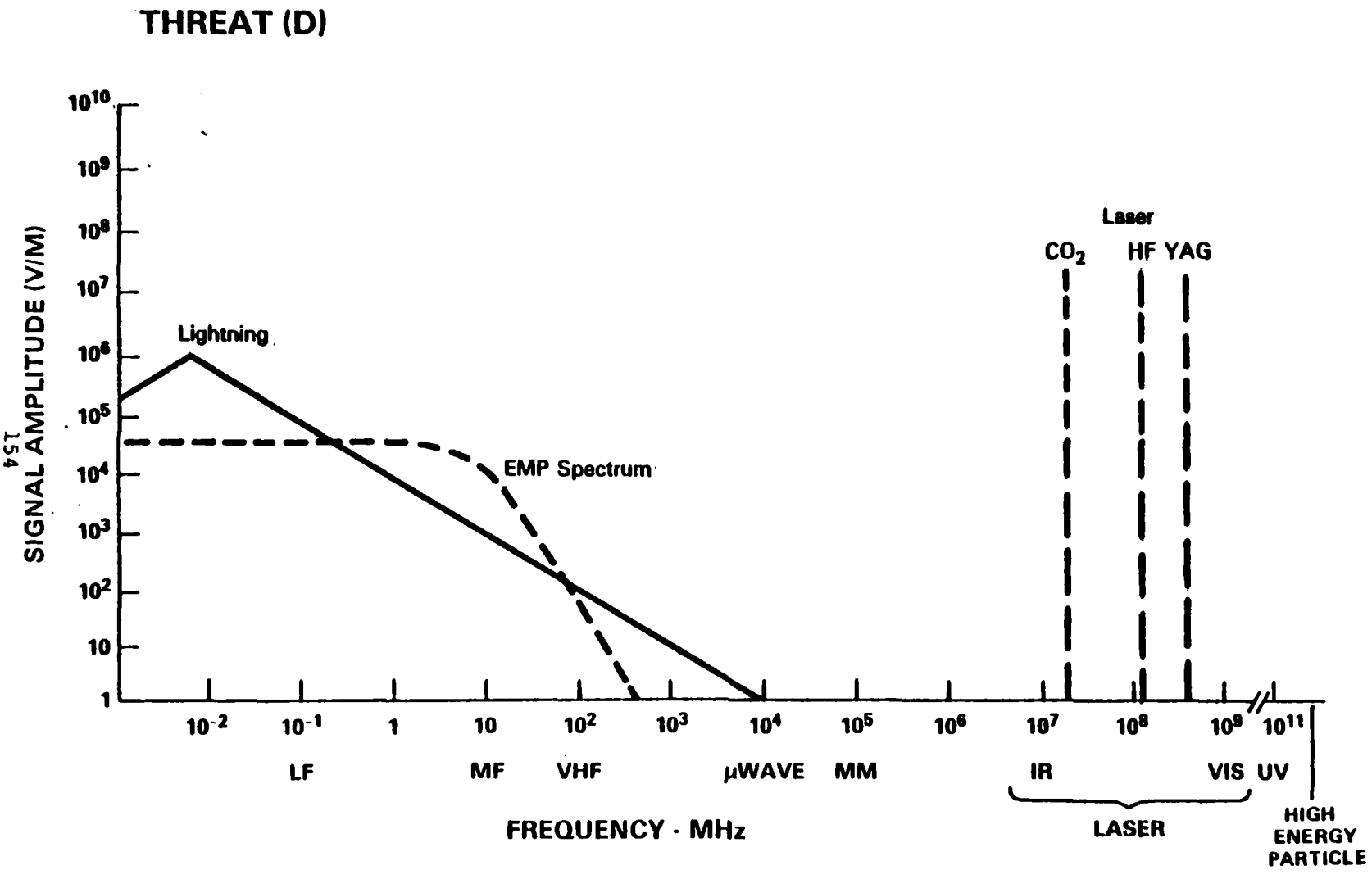


Figure 19. Threat Spectrum

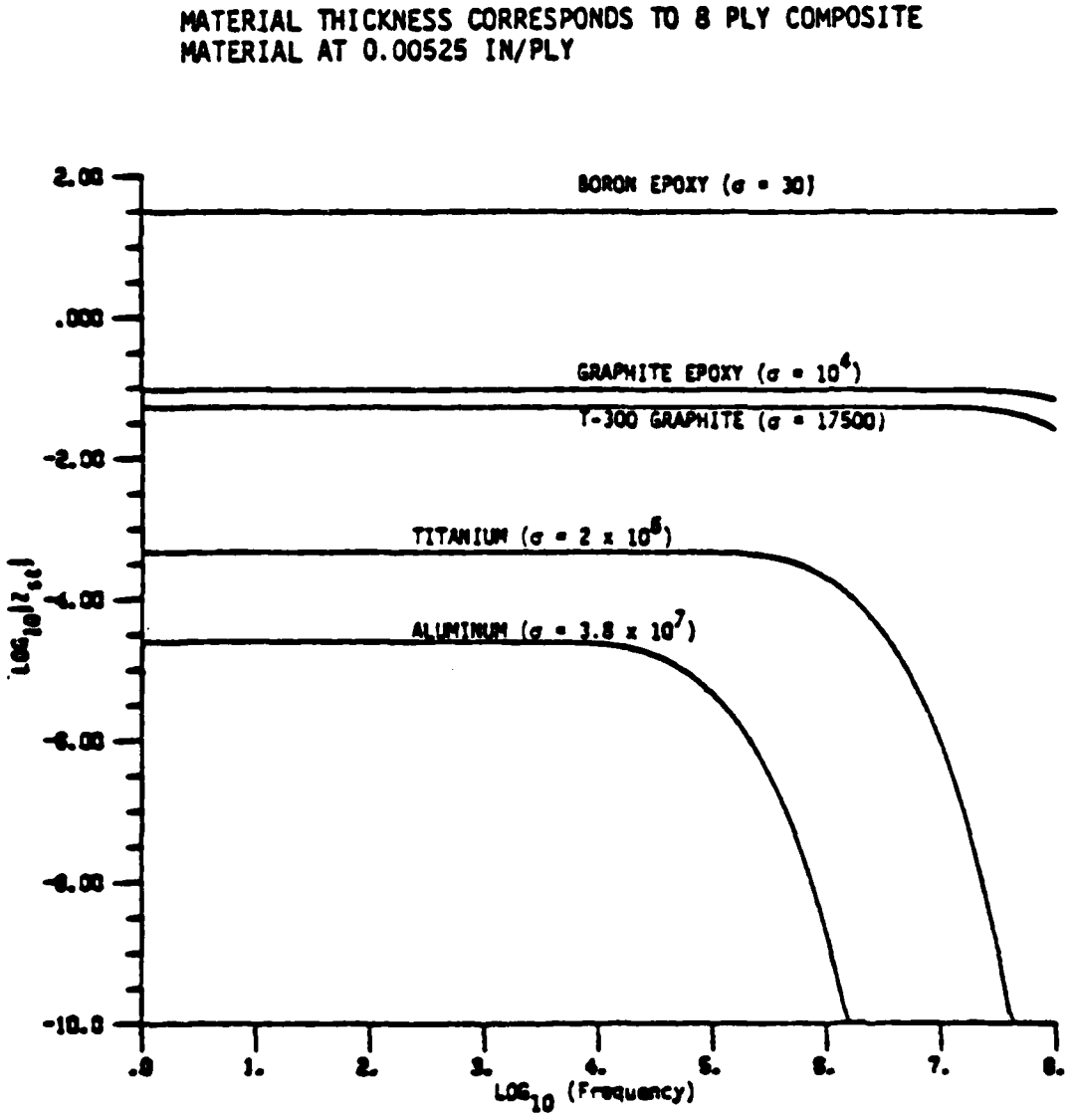


Figure 20. Surface Transfer Impedances for Different Materials

EM PROTECTION OF METALS AND COMPOSITES (T_e)

Transfer Impedance Shielding of Structural Materials and Protective Electromagnetic Coatings

(Valid for Frequencies Below 10^5 Hz)

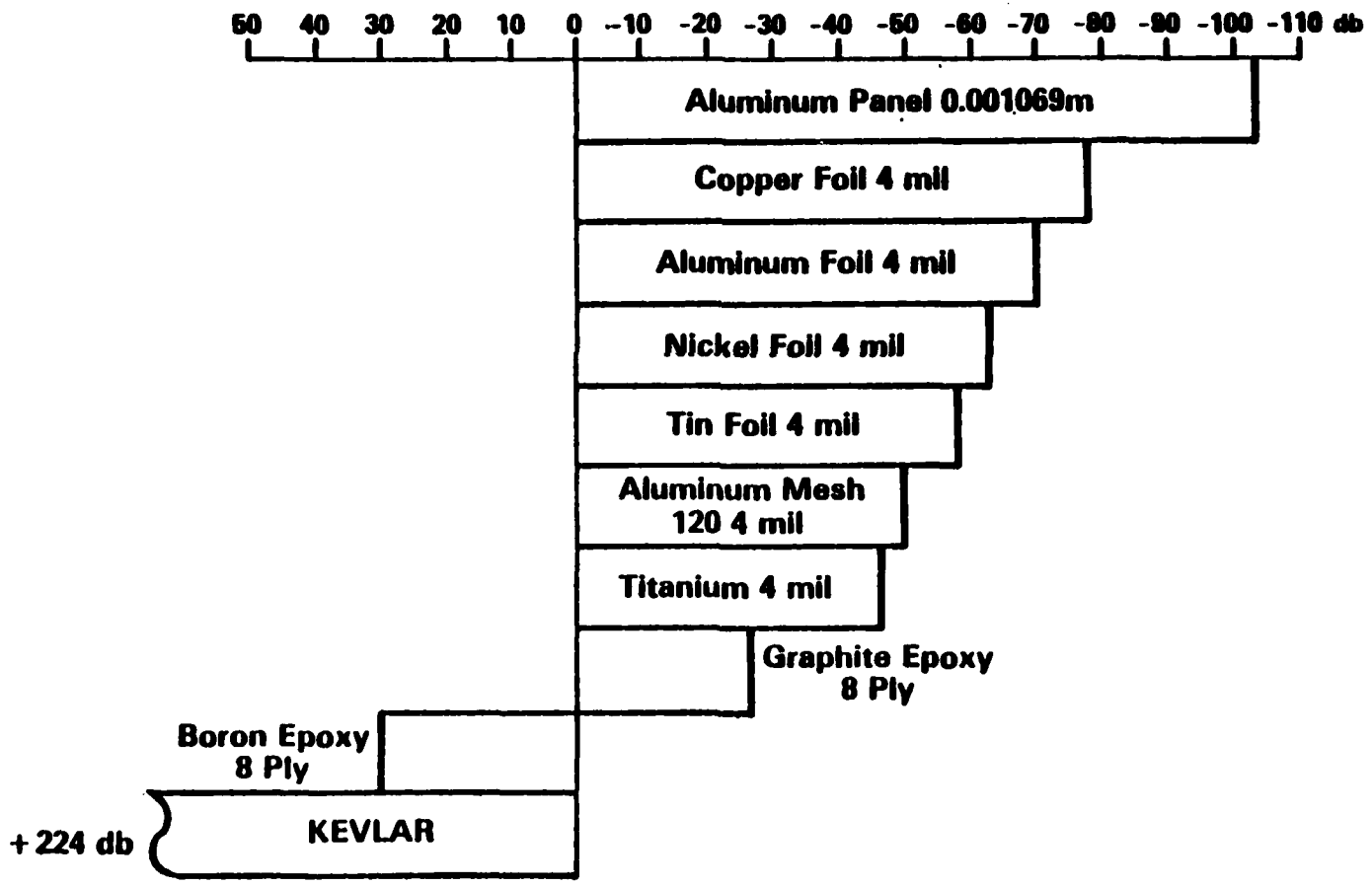


Figure 21. Transfer Impedance Shielding of Structural Materials and Protective Electromagnetic Coatings

AIRFRAME SHAPE (T_2)

The Shape of an Aircraft Influences EM Coupling

MAGNETIC SHIELDING EFFECTIVENESS for a Uniform Incident Magnetic Field. SHIELD CONDUCTIVITY = 10^4 Ω/m. Shield Thickness = 0.00107 m (CORRESPONDING TO 8 PLY Composite Material at 0.00525 In/Ply)

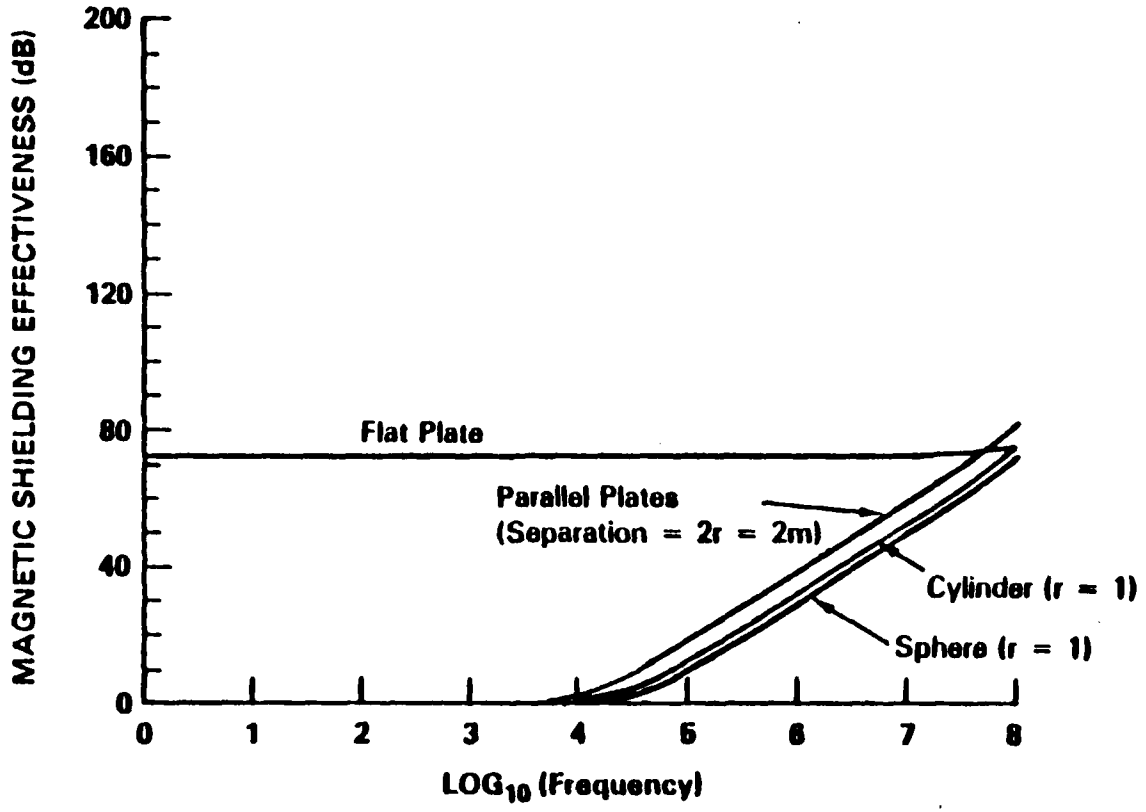


Figure 22. Magnetic Shielding Effectiveness for Various Shapes

AIRFRAME SHAPE (T_2)

MAGNETIC SHIELDING EFFECTIVENESS of an Enclosure Under a Uniform Magnetic Field as a Function of Volume-To-Surface Ratio. SHIELD CONDUCTIVITY = 17500 Ω/m. Shield Thickness = 0.00107 m (CORRESPONDING TO 8 PLY Composite Material at 0.00525 In/Ply)

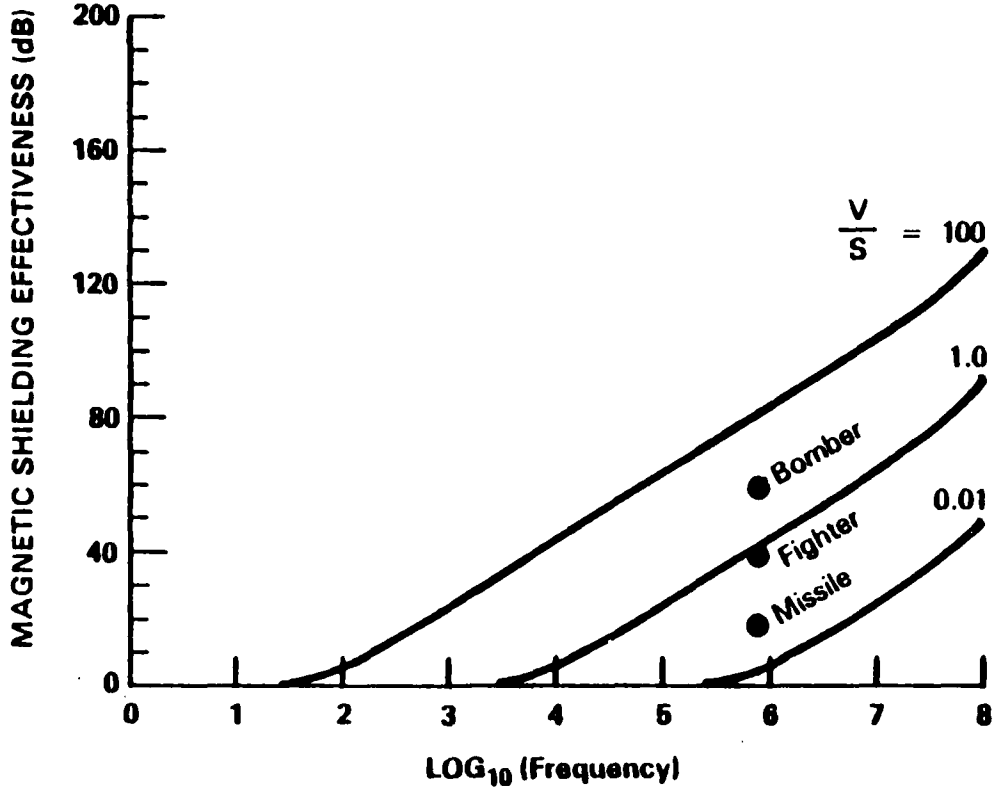


Figure 23. Magnetic Shielding Effectiveness for Various Shapes

MATERIAL SHIELDING (T_1)

Composite Material Electromagnetic Shielding

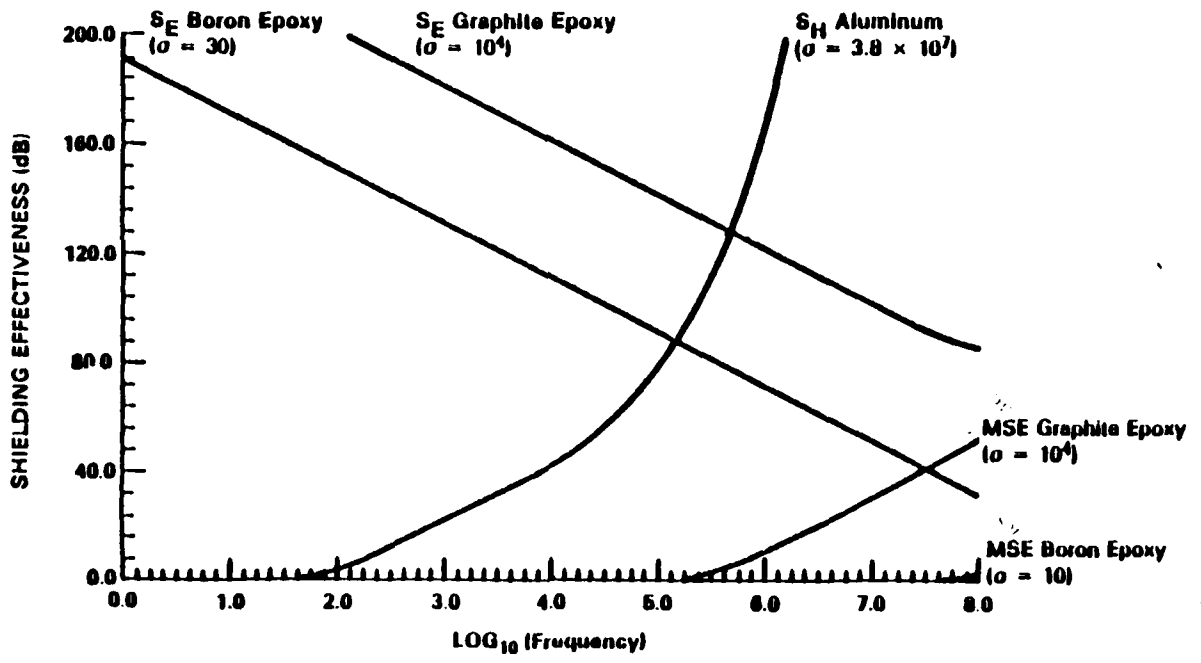


Figure 24. Magnetic S_H and Electric S_H Shielding Effectiveness for Various Materials

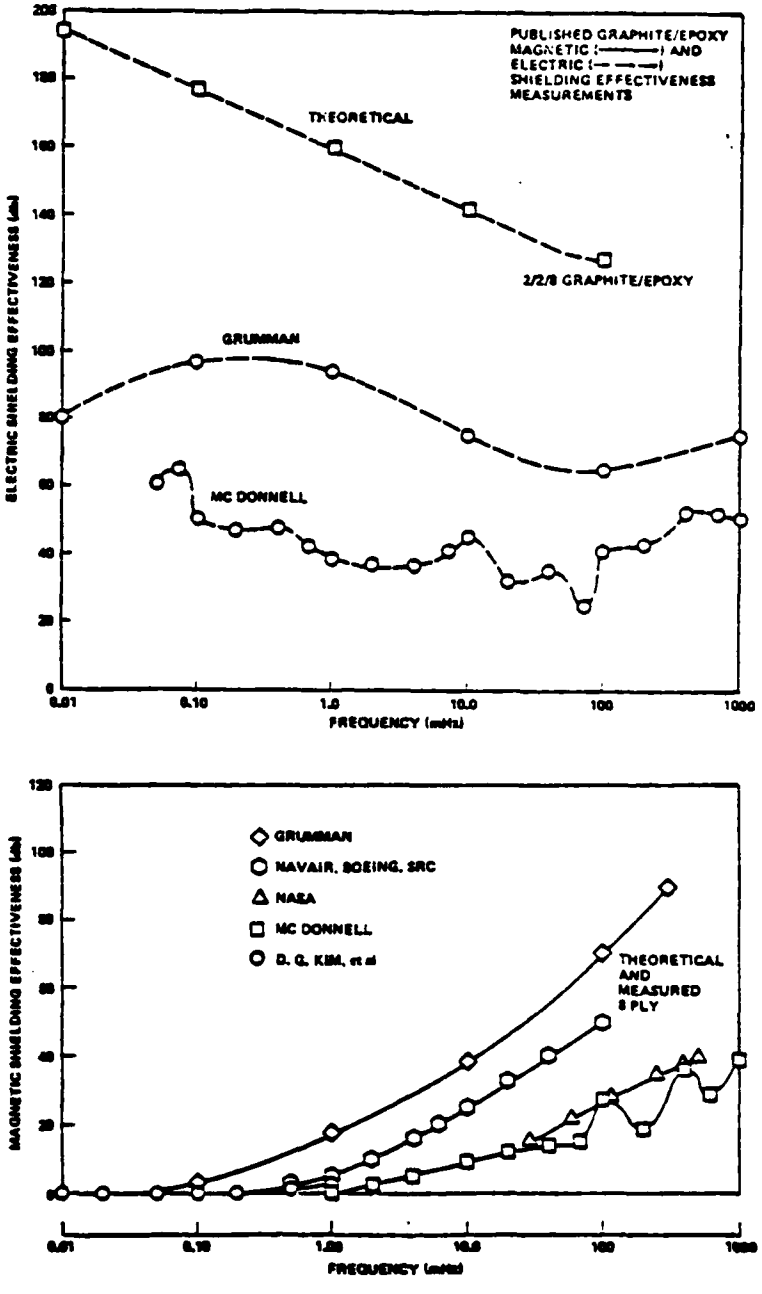


Figure 25. Published Graphite/Epoxy Magnetic and Electric Shielding Effectiveness

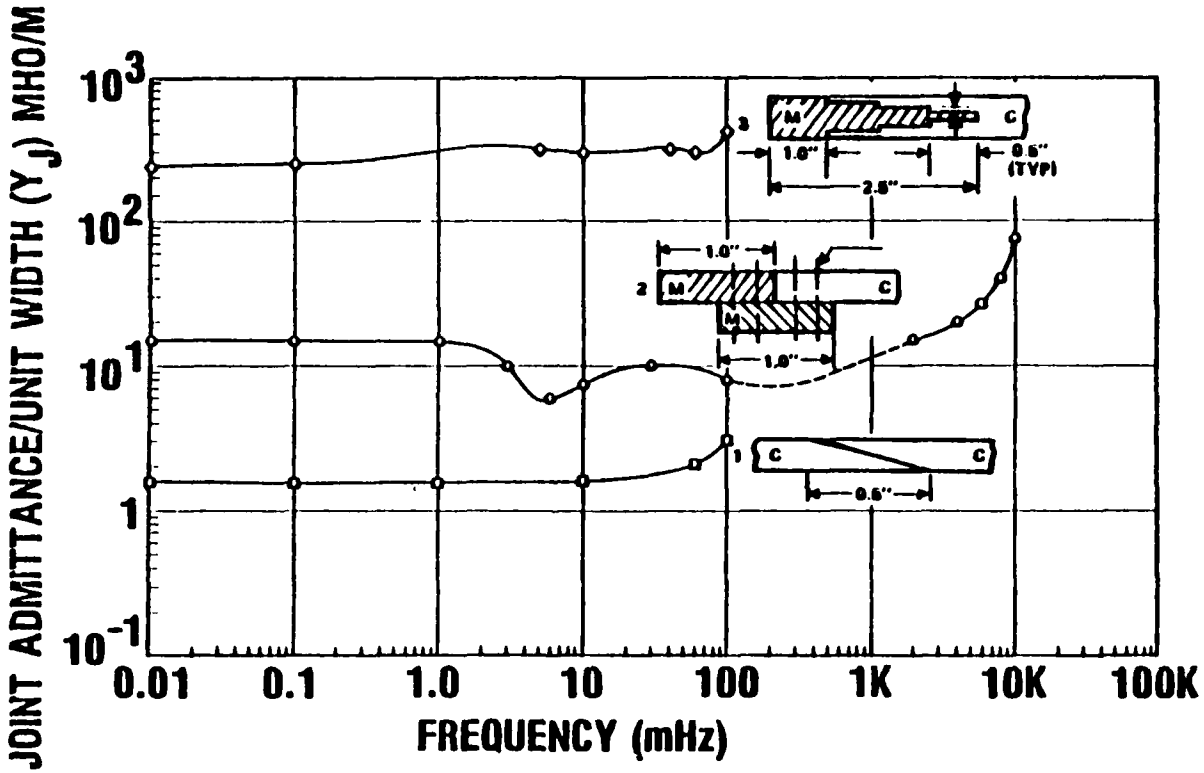


Figure 26. Joint Admittance/Unit Width as a Function of Frequency

TECHNOLOGY TRENDS

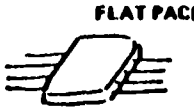
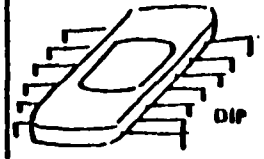
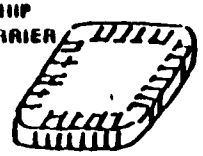
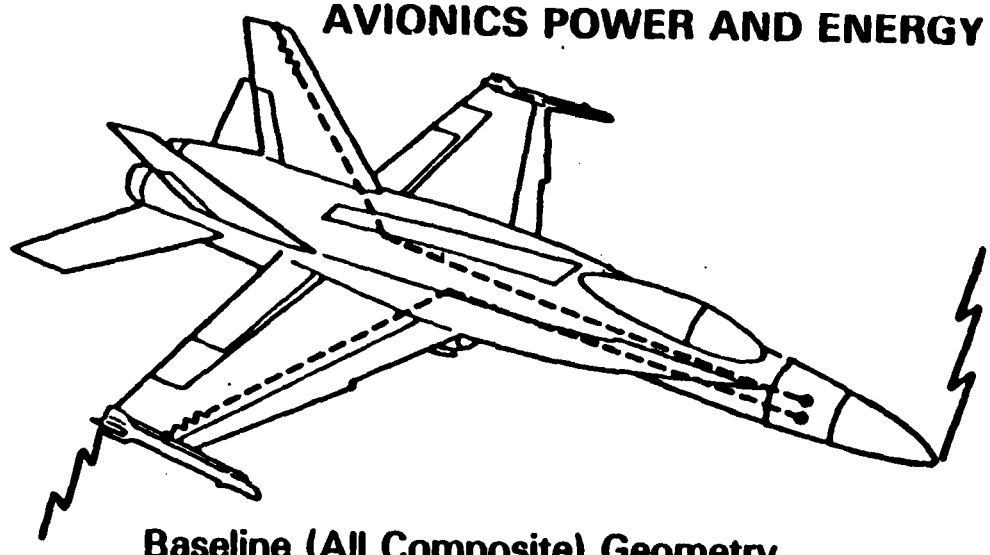
TUBES	DISCRETE TRANSISTORS	INTEGRATED CIRCUITS (IC)	LARGE SCALE INTEGRATED CIRCUITS (LSI)	VERY LARGE SCALE INTEGRATED CIRCUITS (VLSI)
				
250V 1 WATT/DEVICE	12V–24V 10^{-1}–10^{-2} WATTS/DEVICE	5V–12V 10^{-2}–10^{-3} WATTS/TRANS	5V–7V 10^{-3}–10^{-4} WATTS/TRANS	1.5V–3V 10^{-5}–10^{-6} WATTS/TRANS
GLASS/ METAL/ CERAMIC	METAL/ CERAMIC	METAL/ CERAMIC/ EPOXY	METAL/ CERAMIC/ EPOXY	CERAMIC/ EPOXY
F-9	F-4	F-14	F-18	VSTOL
ALUMINUM	ALUMINUM	ALUMINUM/TITAN	GRAPHITE-EPOXY ALUMINUM	GRAPHITE-EPOXY ?
PRE-1960's	1950's	1960's	1970's	1980's

Figure 27. Aerospace Technology Trends

AVIONICS POWER AND ENERGY



Baseline (All Composite) Geometry

Peak Power and Maximum Energy

Direct Strike	V_{ij} (Volts)	i_{ij} (Amps)	P_{ij}^{peak} (Kilowatts)	E_{ij} (Joules)
Nose/Tail Wire (Nose/Tail Attachment)	32,000	1,100	3,520	1035.2 J
(Nearby Strike)	250	8.2	2	0.069 J
Nose/Wing Tip Wire (Nose/Tail Attachment)	6,500	220	1,430	42.06 J
(Nose/Wing Tip Attachment)	17,000	550	9,350	276.0 J

Figure 28. Voltage, Current, Power, and Energies Caused by LEMP and NEMP External Fields on a Meter Long Power Line in an Aluminum or Graphite/Epoxy Fuselage

EM PROTECTION (T_6)

Protective Coatings Improvement Relative to 8-Ply G/E

(Valid for Frequencies Below 10^5 Hz)

$$\frac{Z_{ST}\ (8\text{-Ply Graphite Epoxy})}{Z_{ST}\ (\text{Coating}}$$

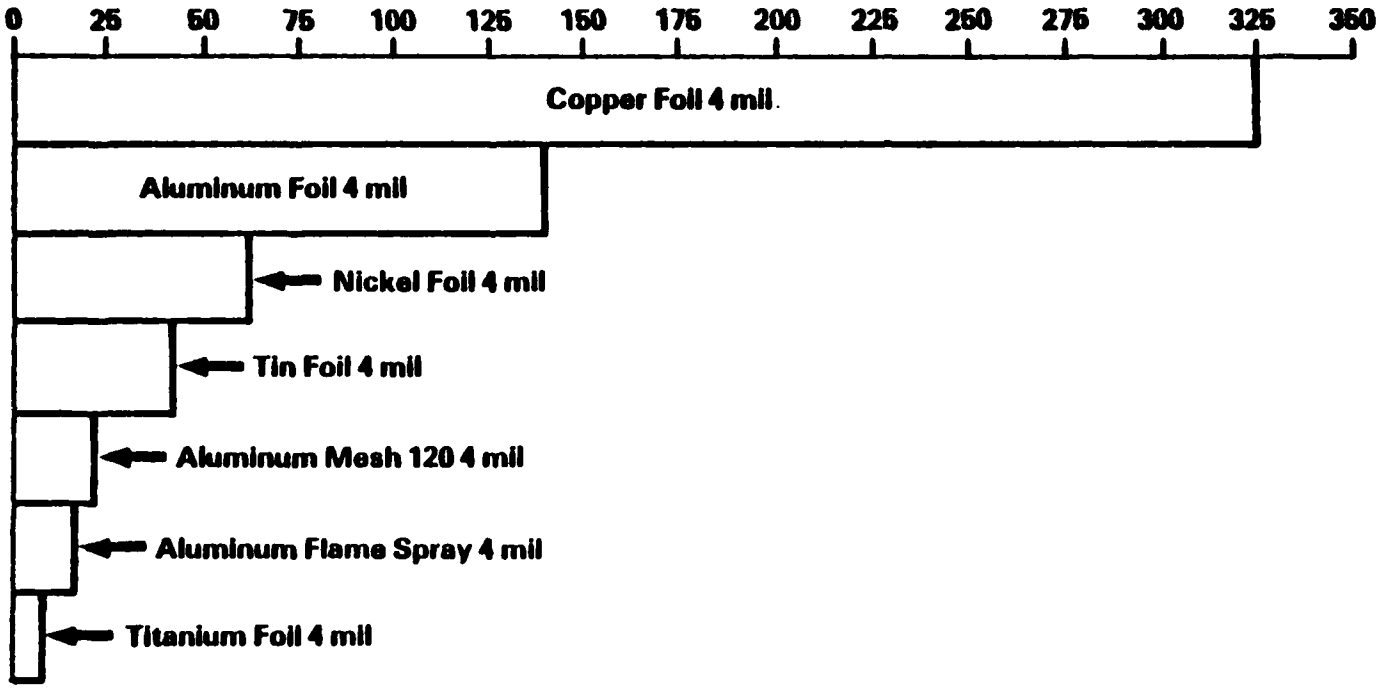


Figure 29. Improvement Protective Coatings Provided Relative to 8-Ply Graphite/Epoxy

EM PROTECTION WEIGHT PENALTIES (T_e)

Forward Fuselage AV-8B (Area - 100 Ft^2) Weight Penalty (Pounds) Imposed by Electromagnetic Protective Coatings

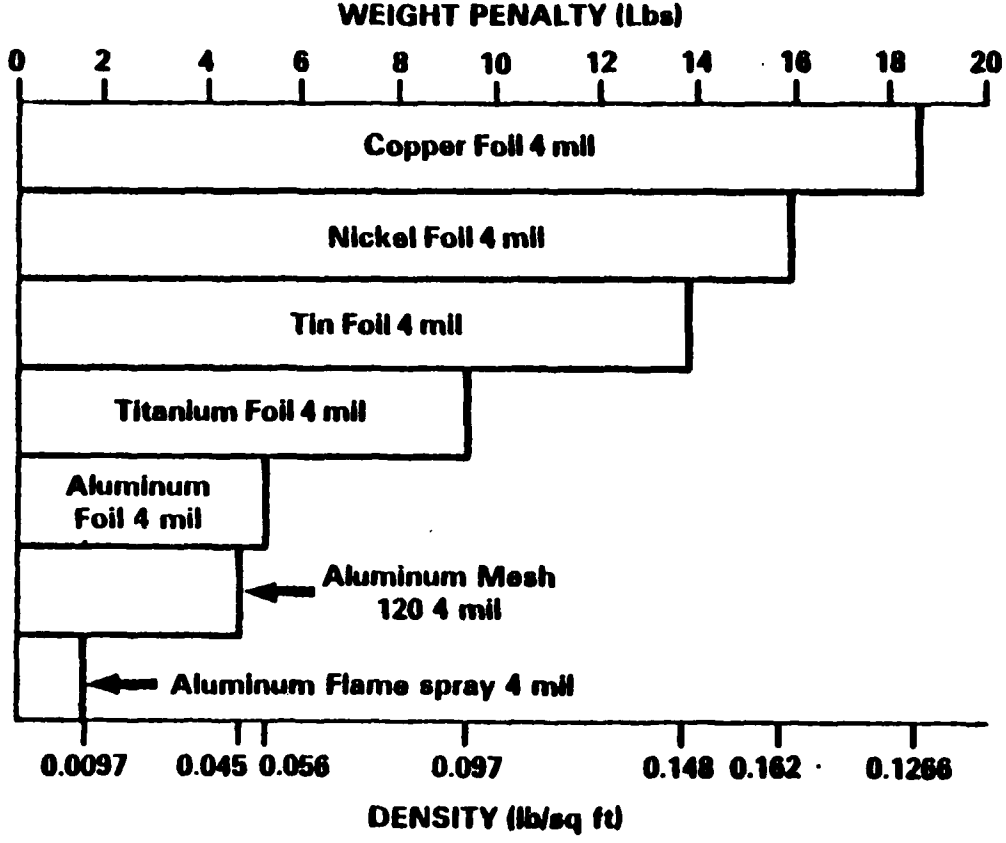


Figure 30. Weight Penalty Imposed by Protective Coatings

EM PROTECTION (T_6)

Weight Shielding Figure of Merit

(Protection Beyond 8-Ply G/E Provided by the Weight of 1 Square Foot of Protective Coating)

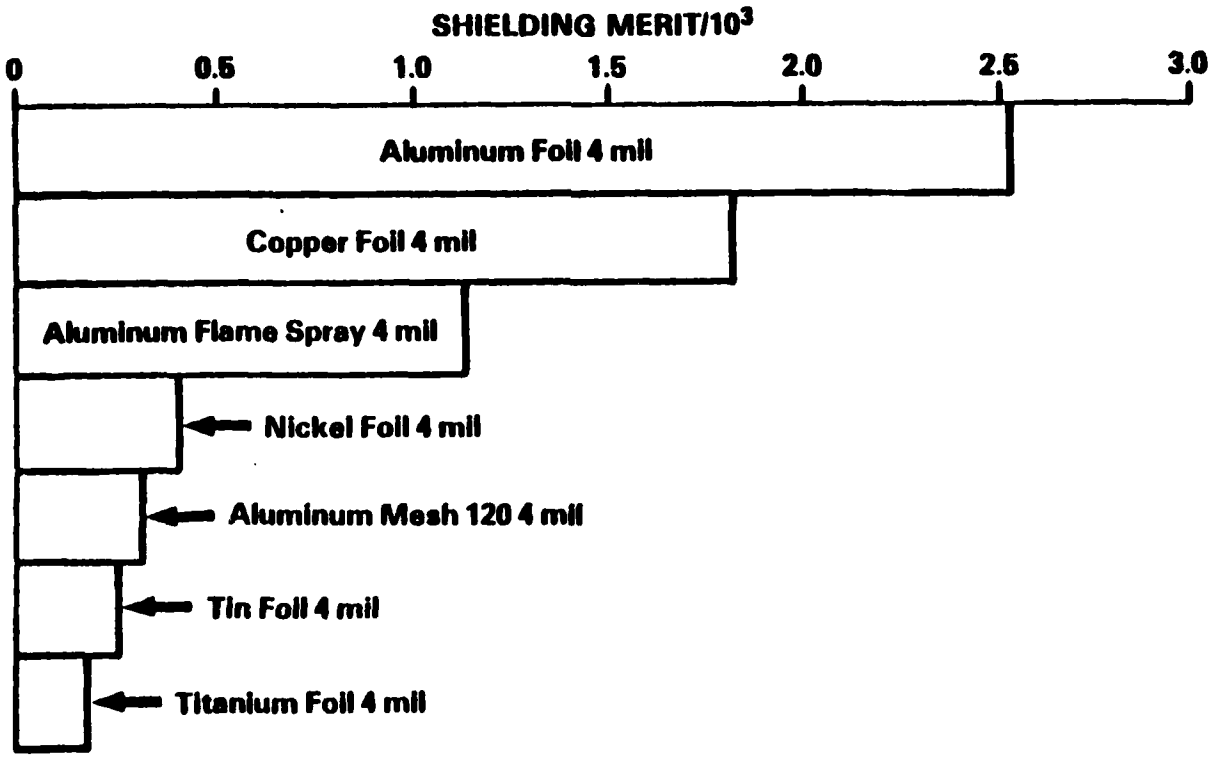


Figure 31. Weight/Shielding Figure of Merit of EM Protective Coatings

COMPUTER-AIDED AIRCRAFT CONCEPTUAL DESIGN CAPABILITY IN THE NAVAL AIR SYSTEMS COMMAND AND ITS FUTURE DEVELOPMENT

Rudi F. Saenger
Naval Air Systems Command
Washington, D.C.

COMPUTER-AIDED AIRCRAFT CONCEPTUAL DESIGN CAPABILITY IN THE NAVAL AIR SYSTEMS COMMAND AND ITS FUTURE DEVELOPMENT

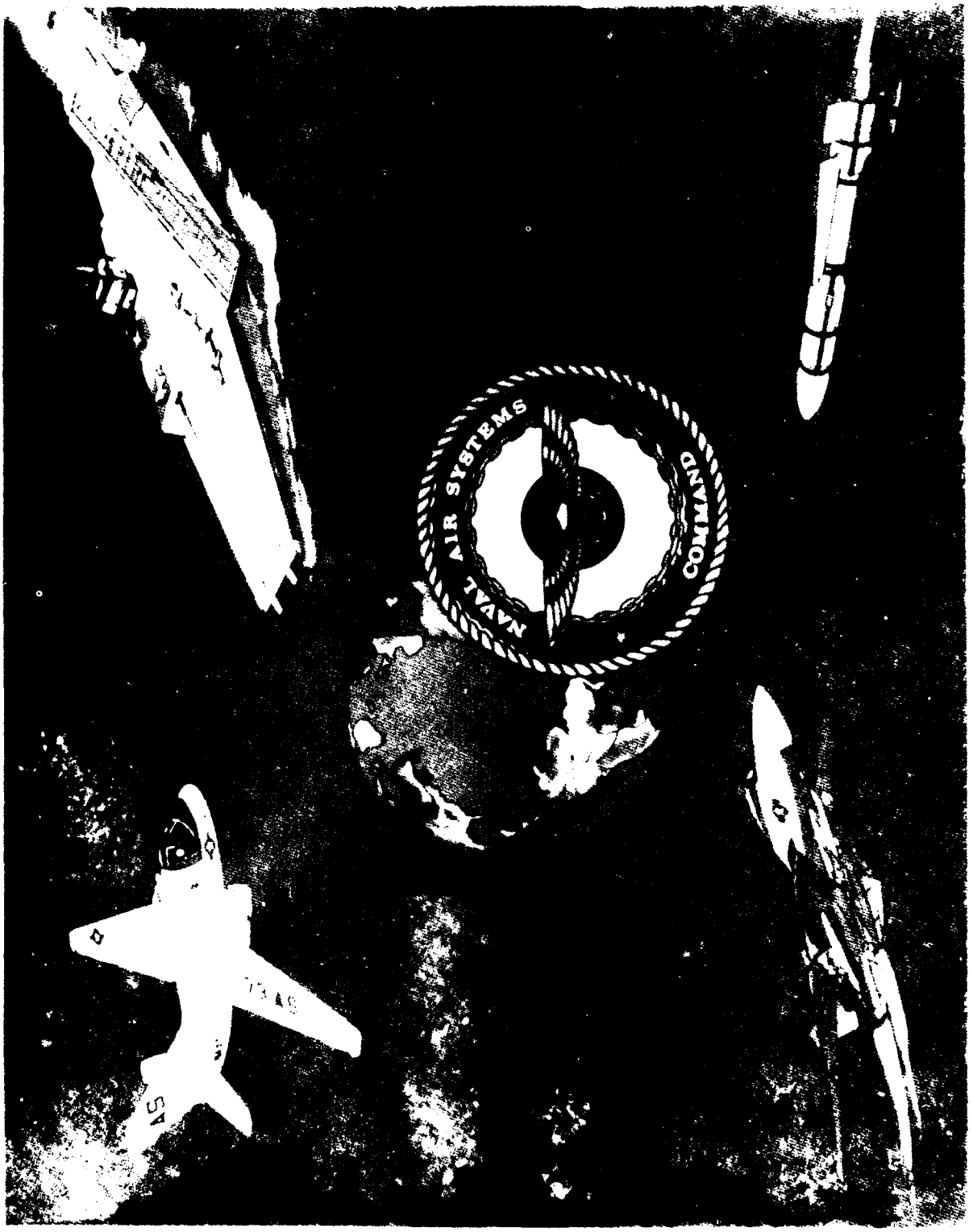
Rudi F. Saenger
Naval Air Systems Command
Washington, D.C.

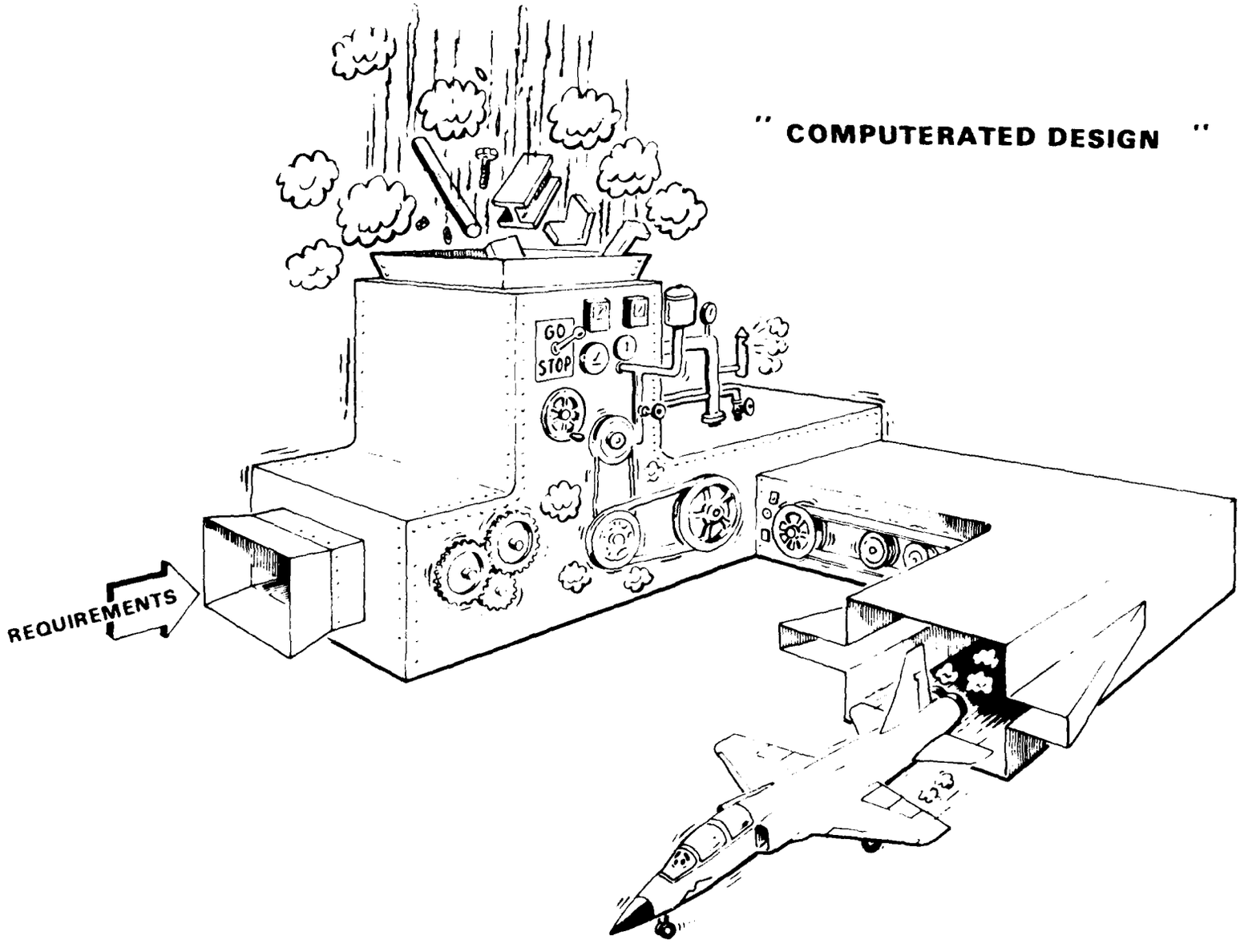
Computer-aided aircraft conceptual design, more and more, is becoming a necessity for both government and industry alike. Some of the reasons for this are dramatically expanding technology, competition from other countries, greatly increased workload, shortened response time, reduced numbers of personnel, and present inefficient use of critical skills. Given the enormously increased and increasing cost of aircraft, and the tendency to extend service life years beyond initial plans, it has become vital to optimize every possible aspect of aircraft conceptual design. Industry is substantially ahead of government in implementing computer technology. Unless strong steps are taken, NAVAIR will soon be:

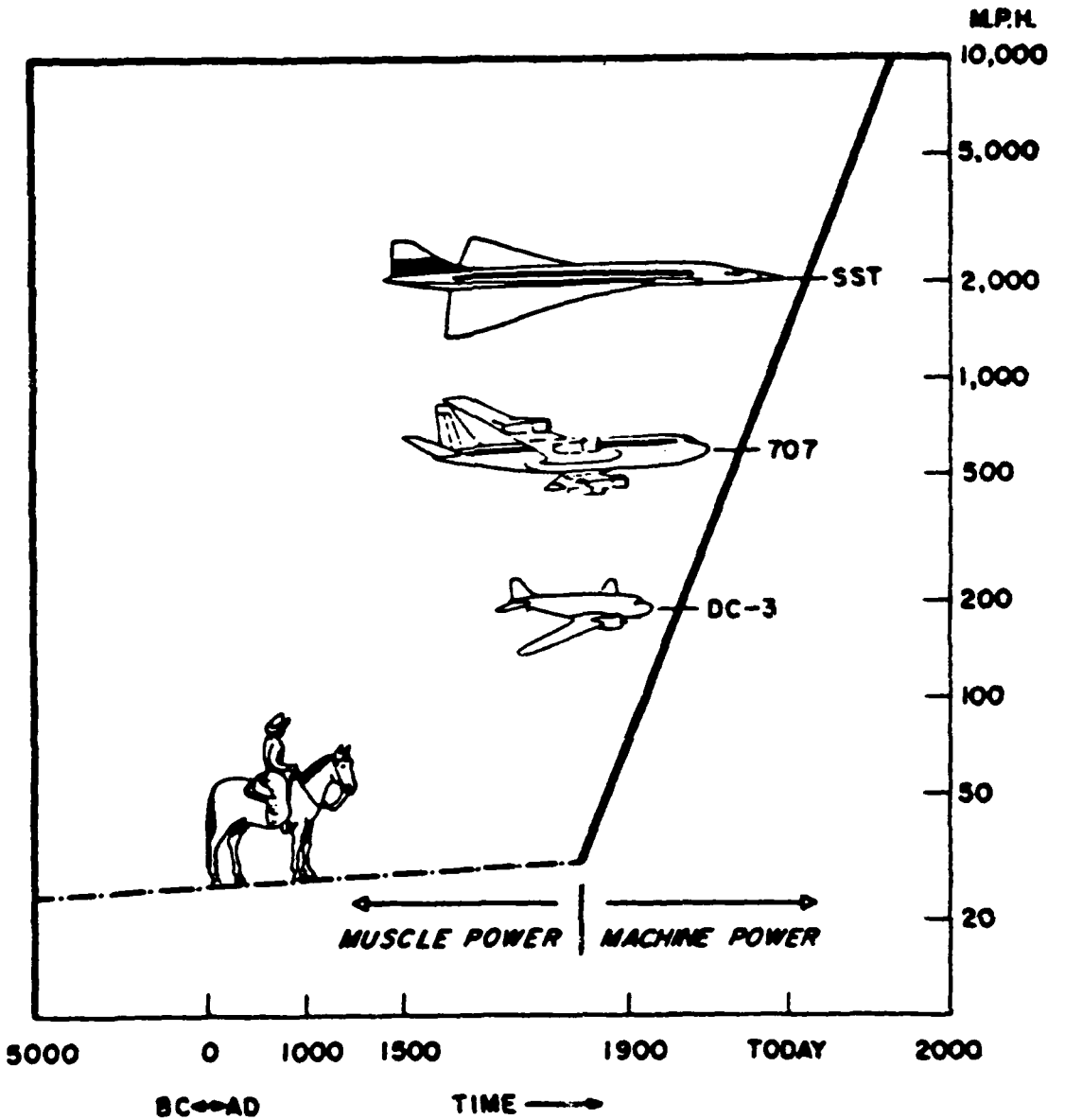
- Unable to pass judgment on future designs
- Losing ground relative to industry in technology development
- Unable to respond in a timely fashion to work requested by higher authority.

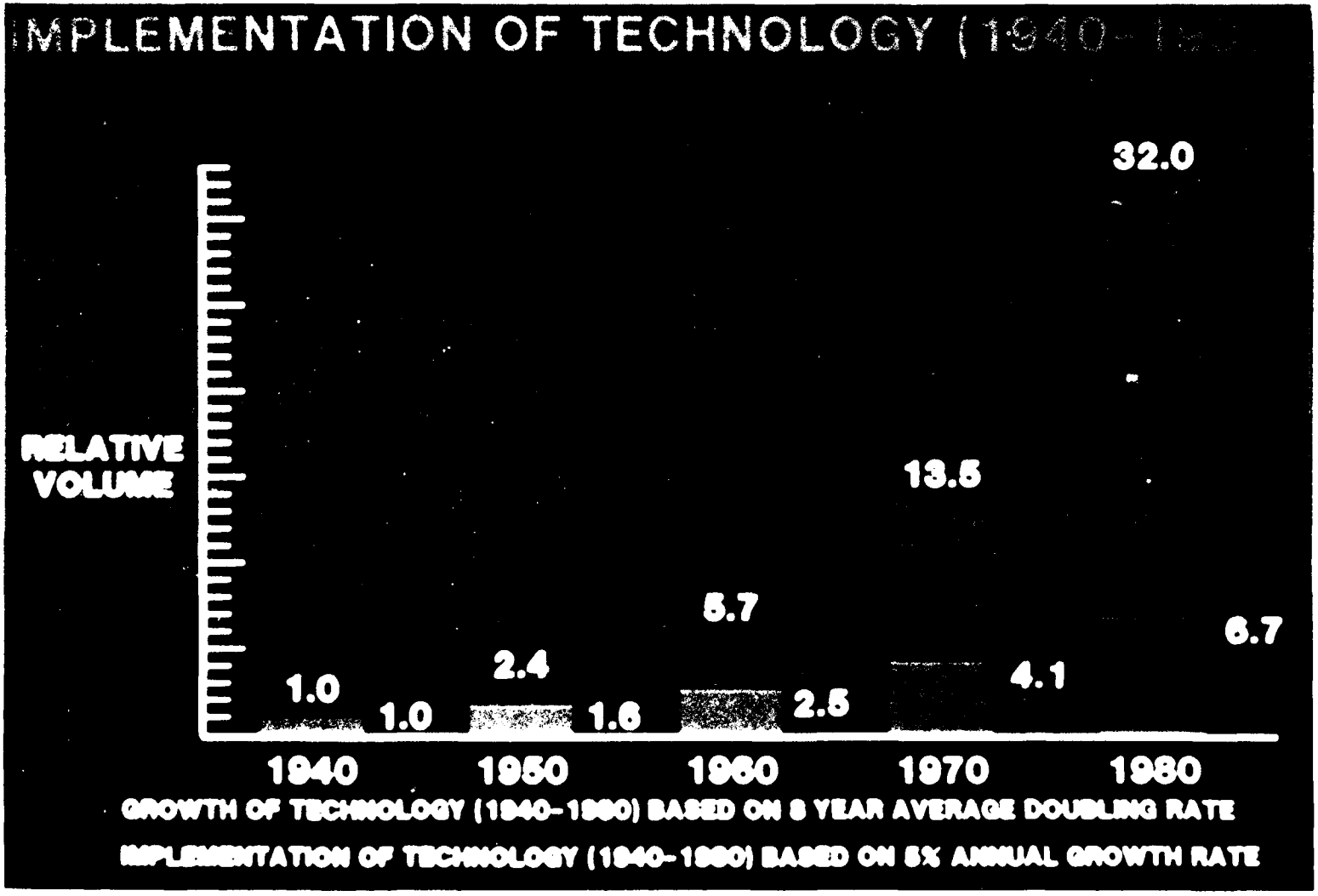
NAVAIR has established the NAVAIR Integrated Computer-Aided Design (NICAD) program to meet this challenge. The program concept calls for computer-aided design capability for aircraft, missiles and helicopters. The first step in building the NICAD system will be defining and acquiring a NAVAIR Aircraft Synthesis Program (NASP). NASP will be based on existing industry and government programs. It will have an extensive compatible format data base with individual modules for dealing with specialized requirements, such as propulsion, aerodynamics, reliability, and survivability to name just a few. The system will be constructed to allow specialists representing the various disciplines to optimize the aircraft through trade studies for each of the critical parameters. The output of such a computer aided design synthesis would be a series of optimum or near optimum design choices from which a final design would be chosen--custom tailored, so to speak--for the operational requirement.

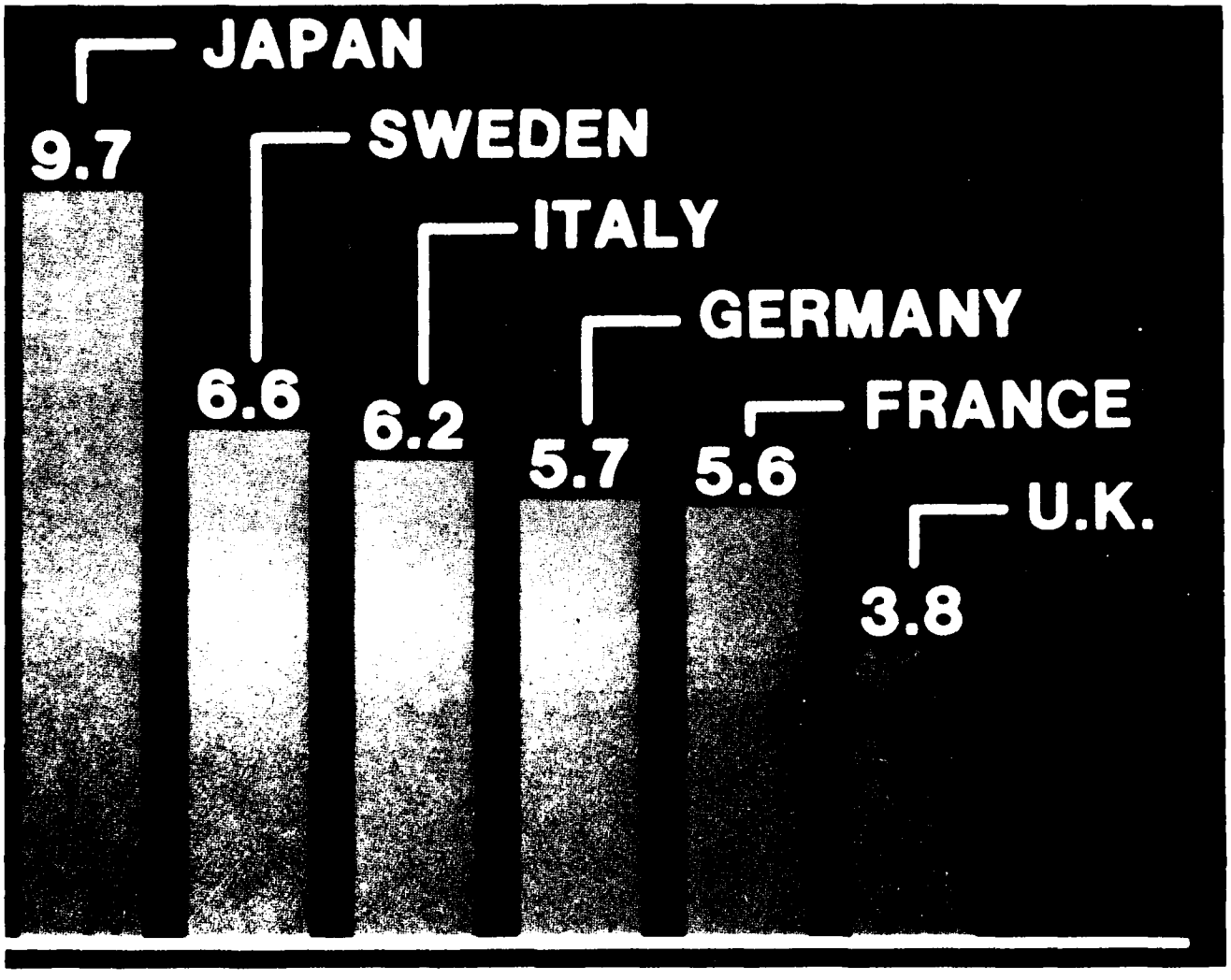
Also planned is a computer graphics type conference room designed to allow presentation of design study results to decision officials. As planned, this facility would allow fielding of questions requiring further computer operation while meetings are in progress. This will expedite decisionmaking while tightly scheduled executives are assembled and eliminate scheduling delays for future meetings or laborious drop cycles.

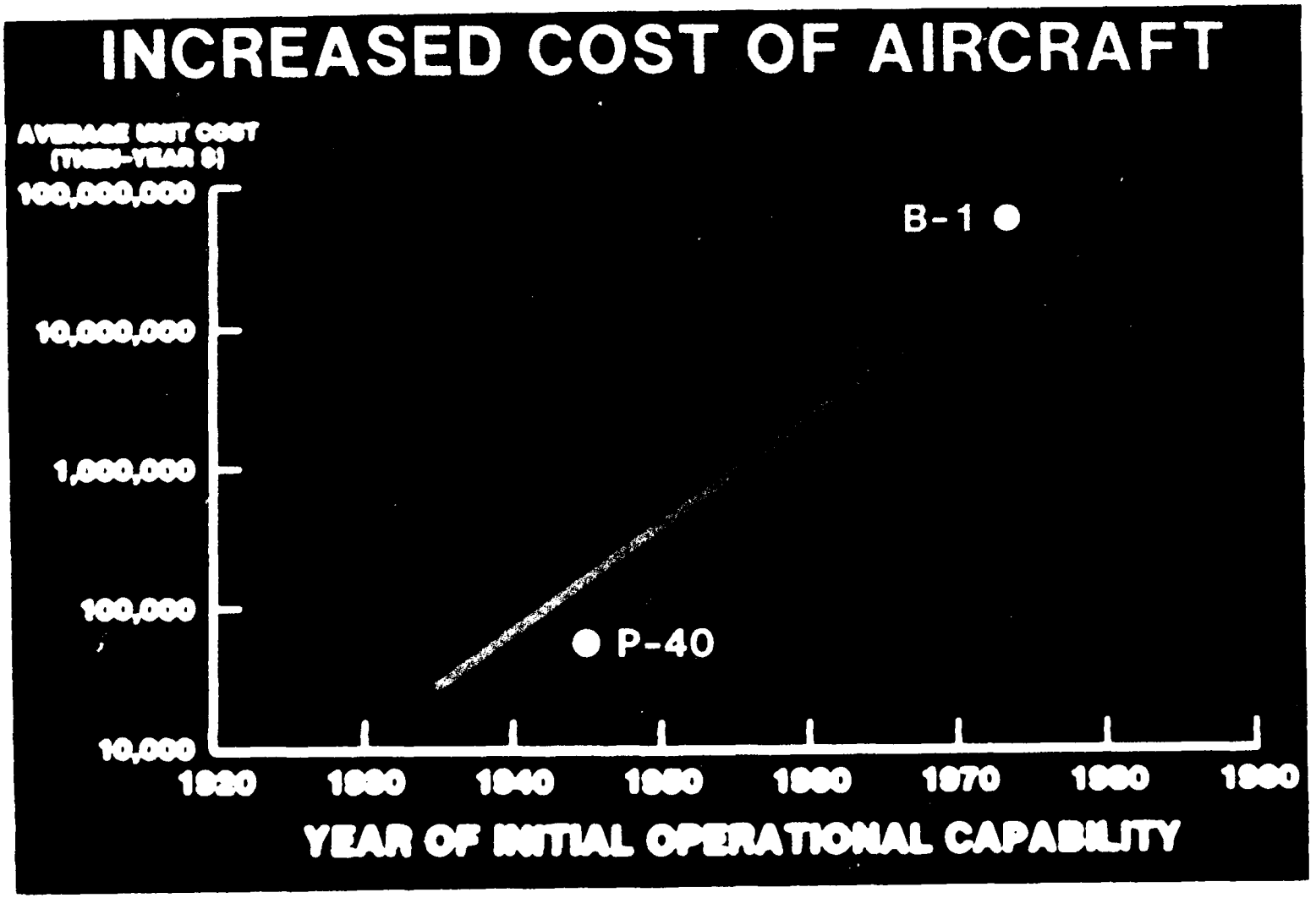

NAVAL AIR SYSTEMS COMMAND


" COMPUTERATED DESIGN "
GO
STOP
REQUIREMENTS


M.P.H.
10,000
5,000
2,000
1,000
500
200
100
50
20
SST
707
DC-3
MUSCLE POWER
MACHINE POWER
5000
0
1000
1500
1900
TODAY
2000
BC⟷AD
TIME ⟶


IMPLEMENTATION OF TECHNOLOGY (1940-
RELATIVE VOLUME
32.0
13.5
6.7
5.7
4.1
2.4
2.5
1.0
1.0
1.6
1940
1950
1960
1970
1980
GROWTH OF TECHNOLOGY (1940-1980) BASED ON 8 YEAR AVERAGE DOUBLING RATE
IMPLEMENTATION OF TECHNOLOGY (1940-1980) BASED ON 5% ANNUAL GROWTH RATE


JAPAN
9.7
SWEDEN
6.6
ITALY
6.2
GERMANY
5.7
FRANCE
5.6
U.K.
3.8


INCREASED COST OF AIRCRAFT
AVERAGE UNIT COST
(THEN-YEAR $)
100,000,000
10,000,000
1,000,000
100,000
10,000
B-1
P-40
1920
1930
1940
1950
1960
1970
1980
1990
YEAR OF INITIAL OPERATIONAL CAPABILITY

CAD = Computor Aided Design

AEROSPACE INDUSTRY CAPABILITIES
IN INTEGRATED AIRCRAFT DESIGN

- GRUMMAN AEROSPACE CORPORATION
  - RAVES (RAPID AEROSPACE VEHICLE EVALUATION SYSTEM)
    - IBM 360/370
- ROCKWELL INTERNATIONAL - COLUMBUS AIRCRAFT DIVISION
  - BATCH COMPUTER AIDED DESIGN
    - IBM 360/370
- MCDONNELL AIRCRAFT COMPANY
  - CAD/CAM (COMPUTER AIDED DESIGN/COMPUTER AIDED MANUFACTURING)
    - IBM 2250 GRAPHICS ON IBM 360/370
- VOUGHT CORPORATION
  - ASAP (AIRCRAFT SYNTHESIS ANALYSIS PROGRAM)
    - CDC 777 GRAPHICS ON CDC 6600

AEROSPACE INDUSTRY CAPABILITIES
IN INTEGRATED AIRCRAFT DESIGN

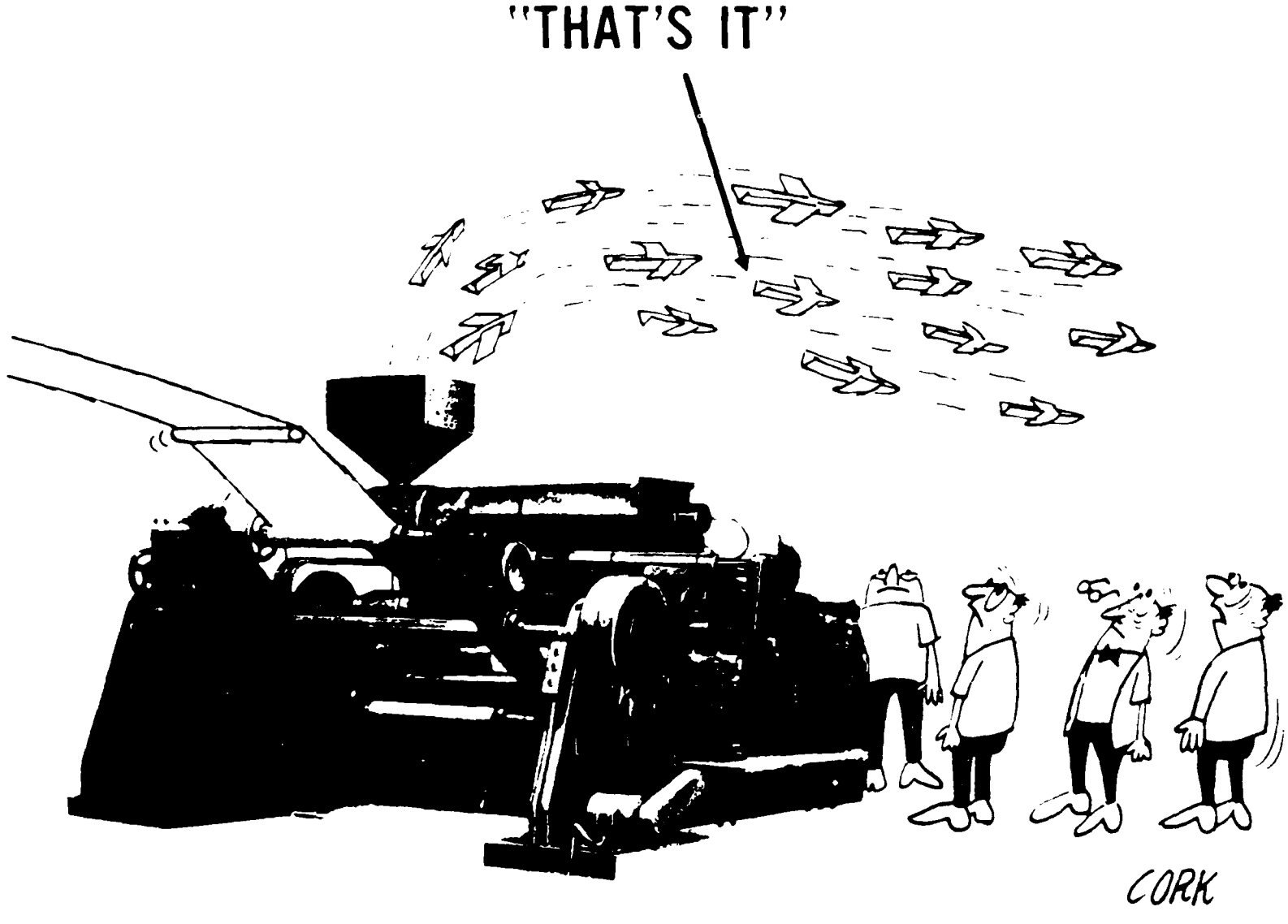
- GENERAL DYNAMICS - CONVAIR DIVISION
  - VDEP (VEHICLE DESIGN AND EVALUATION PROGRAM)
    - CDC CYBER 172 WITH INTERACTIVE GRAPHICS SCOPE
- ROCKWELL INTERNATIONAL - NORTH AMERICAN AIRCRAFT OPERATIONS
  - BATCH COMPUTER AIDED DESIGN
    - IBM 360/370
- LOCKHEED AIRCRAFT CORPORATION
  - CADM (COMPUTER AIDED DESIGN AND MANUFACTURING)
    - IBM 360/370
- DOUGLAS AIRCRAFT CORPORATION
  - ADVANCED DESIGN SIZING PROCEDURE
    - IBM 360/370
- NASA AMES RESEARCH CENTER
  - GASP (GENERAL AVIATION SYNTHESIS PROGRAM)
    - TEKTRONIX SCOPE ON IBM 360 (BEING TRANSFERRED TO CDC 7600)

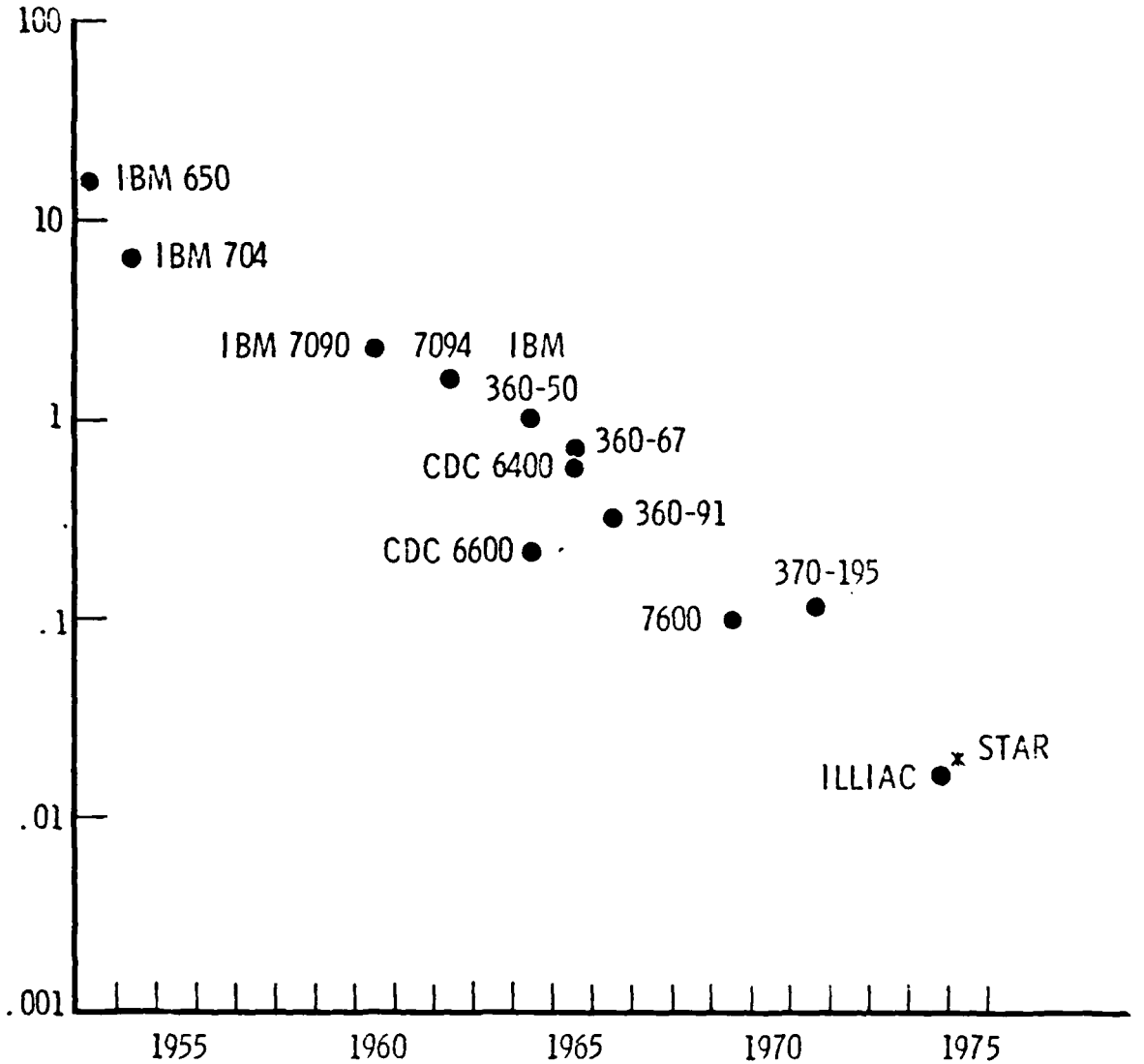
THE PROBLEM

- GREATLY INCREASED WORKLOAD
- SHORTENED RESPONSE TIME
- REDUCED NUMBERS OF PERSONNEL
- INEFFICIENT USE OF CRITICAL SKILLS

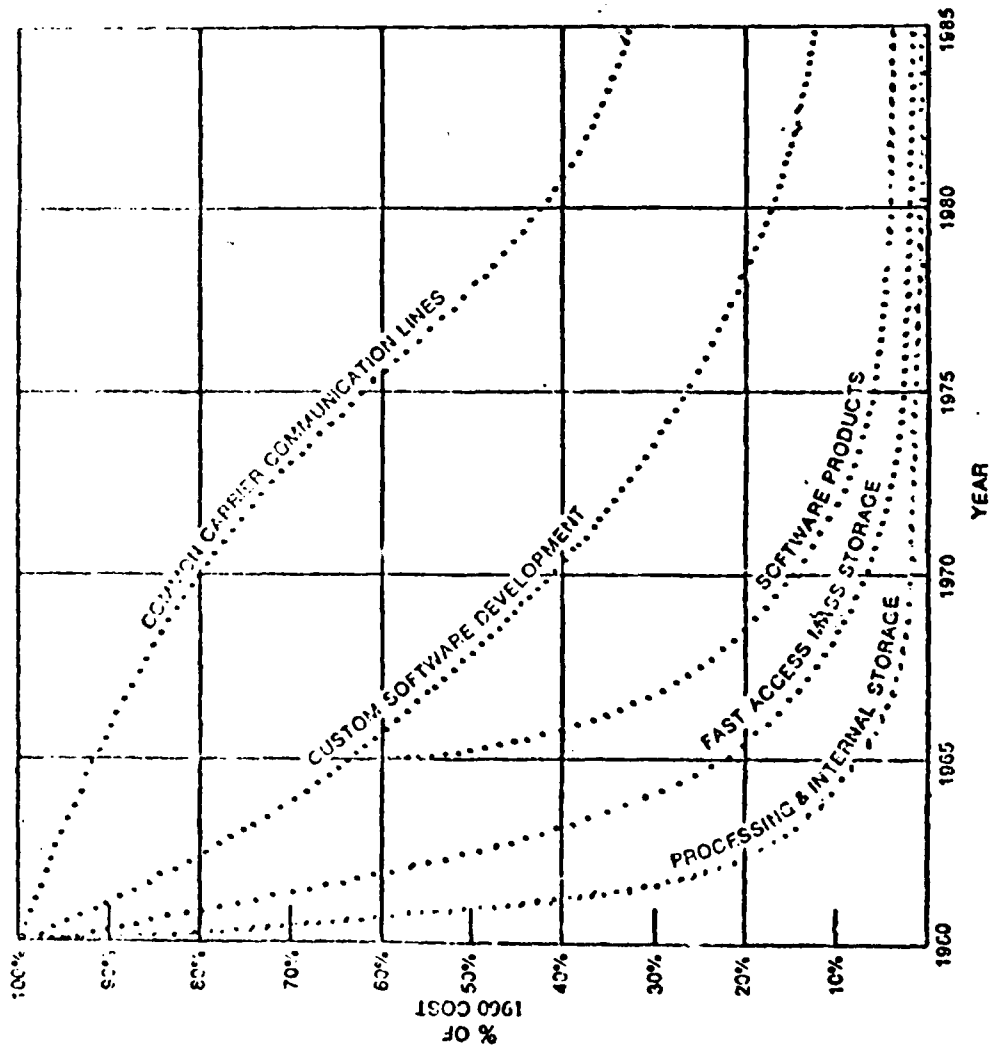
MATACQINST 13100.1

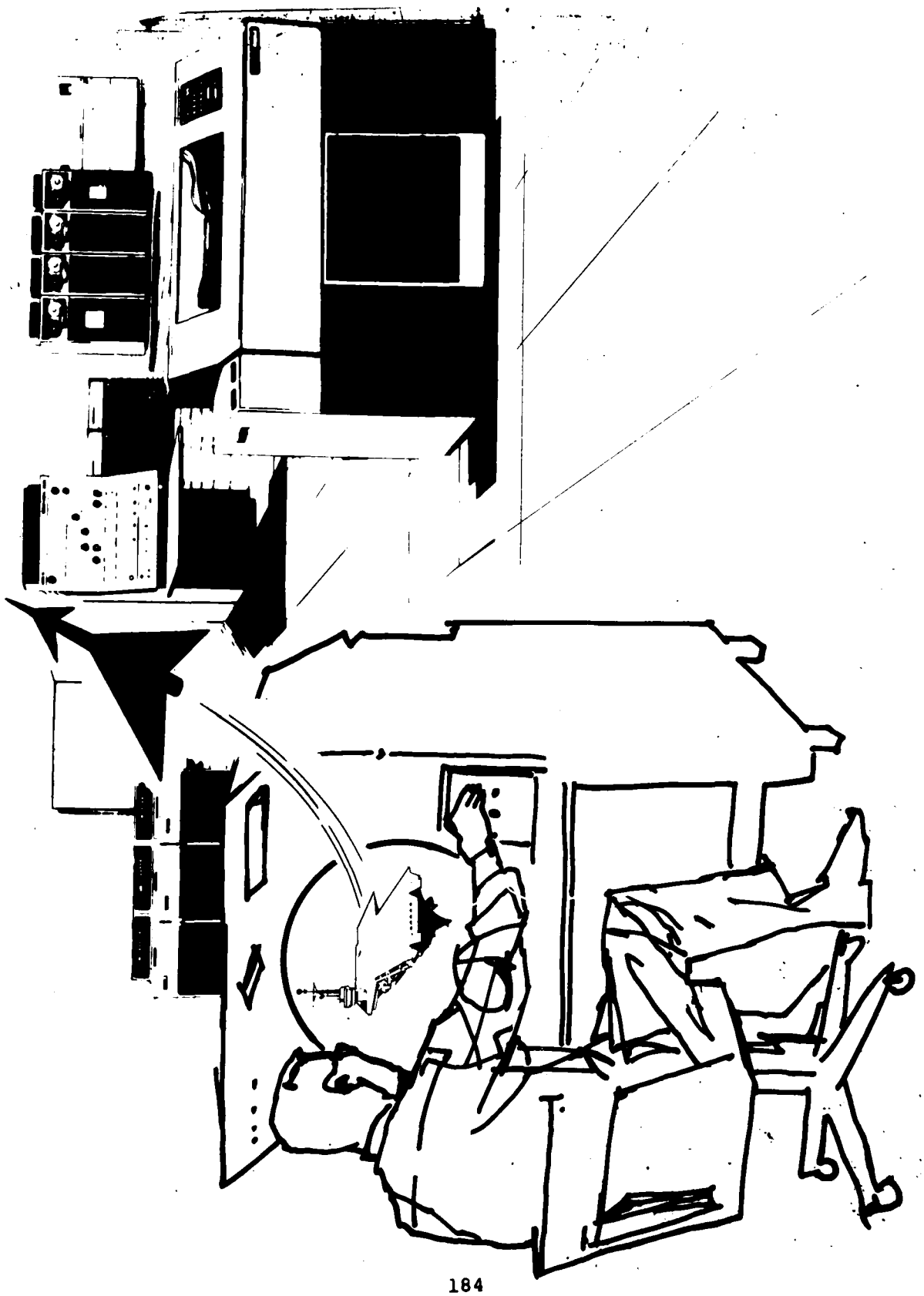
"-----PROVIDES THE POLICY AND PROCEDURES TO ESTABLISH AND IMPLEMENT A COMPUTER-AIDED AIRCRAFT AND MISSILE CONCEPTUAL DESIGN SYSTEM IN THE MATERIAL ACQUISITION GROUP."


"THAT'S IT"
CORK



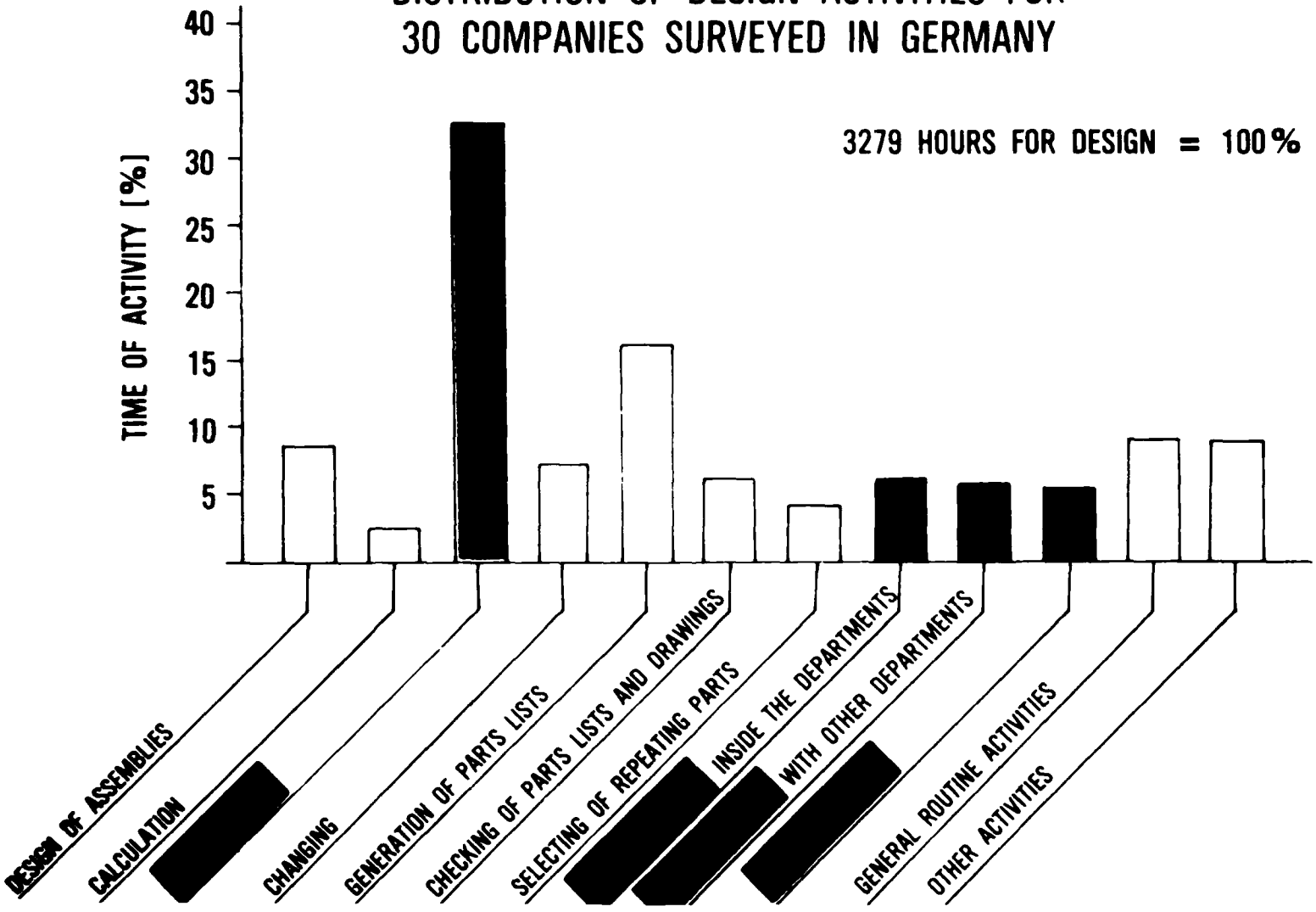
Trend of computation cost for computer simulation of a given flow


COMMON CARRIER COMMUNICATION LINES
CUSTOM SOFTWARE DEVELOPMENT
SOFTWARE PRODUCTS
FAST ACCESS MASS STORAGE
PROCESSING & INTERNAL STORAGE
% OF 1960 COST
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
1960
1965
1970
1975
1980
1985
YEAR

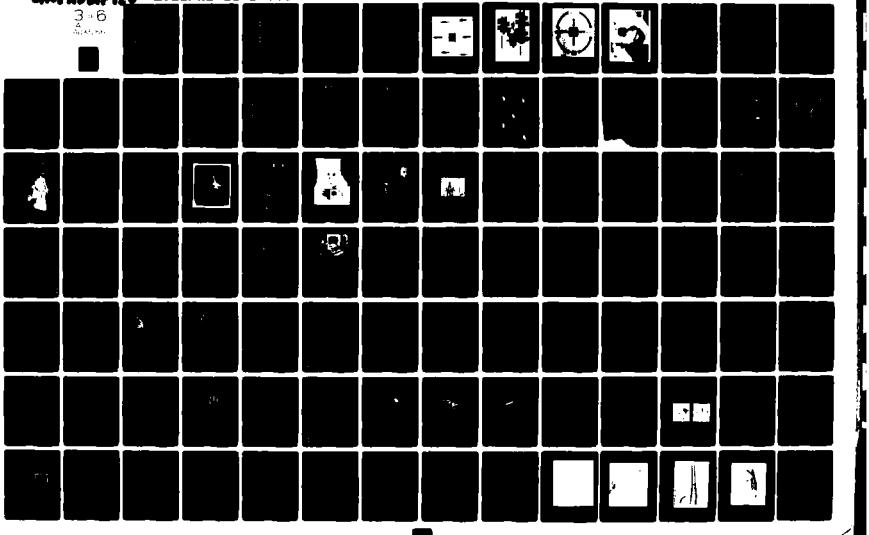


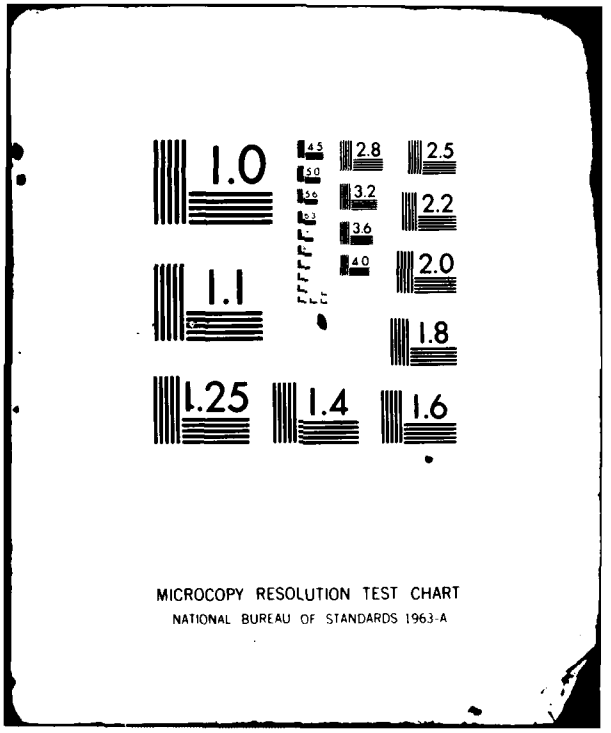
INTEGRATED COMPUTER AIDED DESIGN

DISTRIBUTION OF DESIGN ACTIVITIES FOR 30 COMPANIES SURVEYED IN GERMANY



AD-A113 556 JOINT TECHNICAL COORDINATING GROUP ON AIRCRAFT SURVIV--ETC F/G 1/3
PROCEEDINGS, A WORKSHOP IN SURVIVABILITY AND COMPUTER-AIDED DES--ETC(U)
1981
UNCLASSIFIED JTCG/AS-81-D-001 NL




1.0
1.1
1.25
1.4
1.6
1.8
2.0
2.2
2.5
2.8
3.2
3.6
4.0
4.5
5.0
5.6
6.3
MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS 1963-A

AIRCRAFT

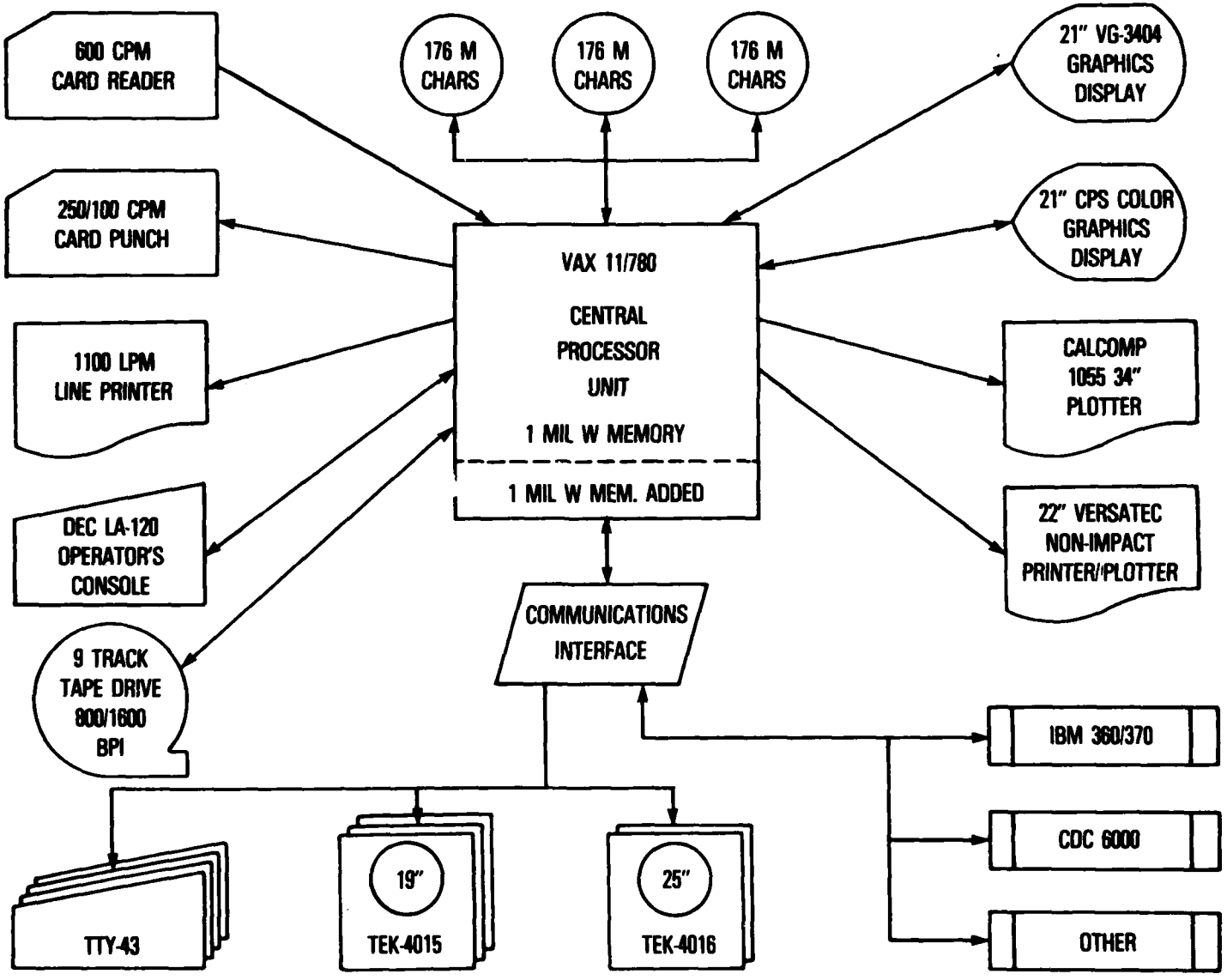
CONTRACTOR PROGRAMS ACQUIRED

- ASAP (LTV - FIGHTER/ATTACK
- VDEP (GENERAL DYNAMICS) - TRANSPORT
- ACSYNT (NASA) - UNUSUAL CONFIGURATIONS
- GASP (NASA) - LIGHT AIRCRAFT
- CDS (ROCKWELL) - GRAPHICS DESIGN

IN-HOUSE PROGRAM GENERATION

- NASP - FIGHTER/ATTACK
  - TRANSPORT
  - TRAINER
  - ?

DIRECT ACCESS DISKS



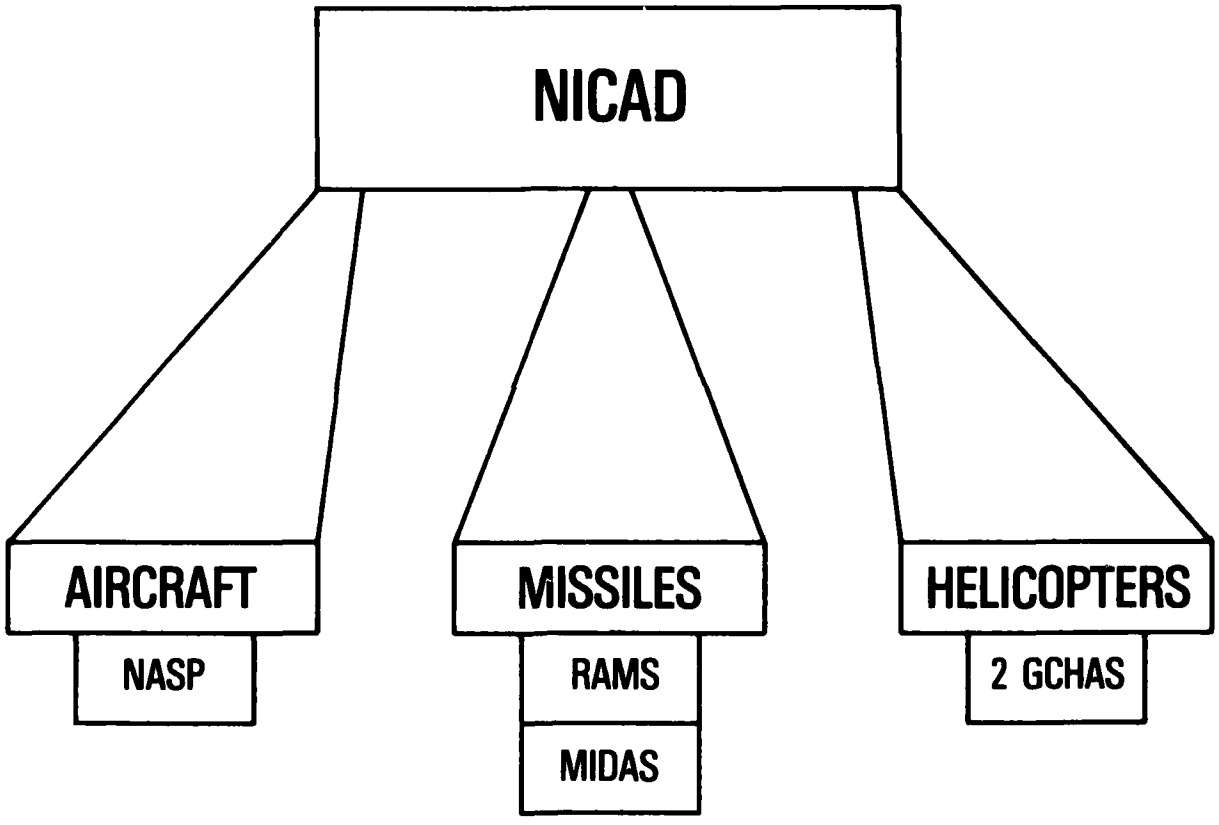
NAVAIR WILL SOON BE:

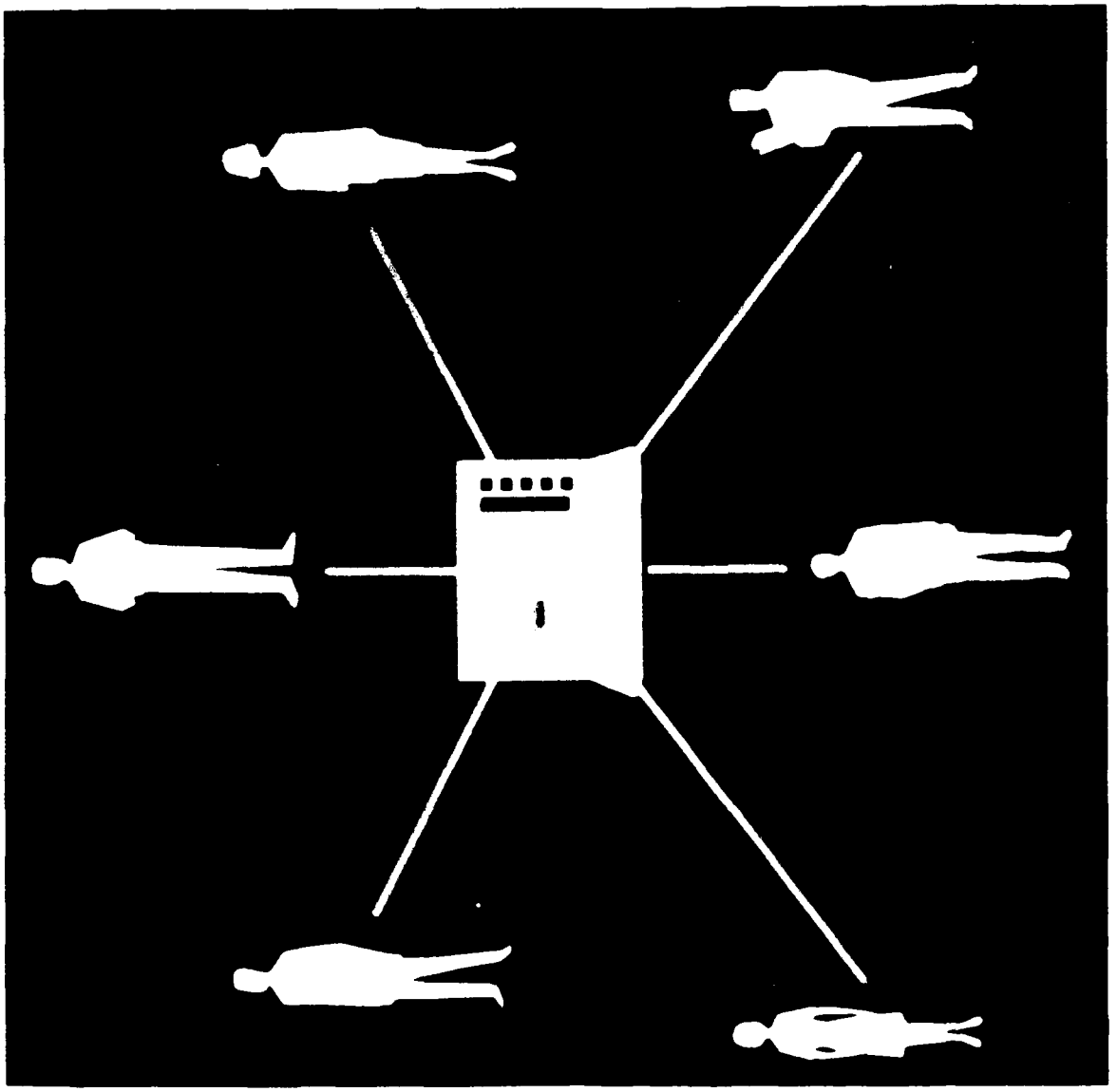
- UNABLE TO PASS JUDGEMENT ON FUTURE DESIGNS
- LOSING GROUND RELATIVE TO INDUSTRY IN TECHNOLOGY DEVELOPMENTS
- UNABLE TO RESPOND IN TIMELY FASHION TO WORK REQUESTED BY HIGHER AUTHORITY

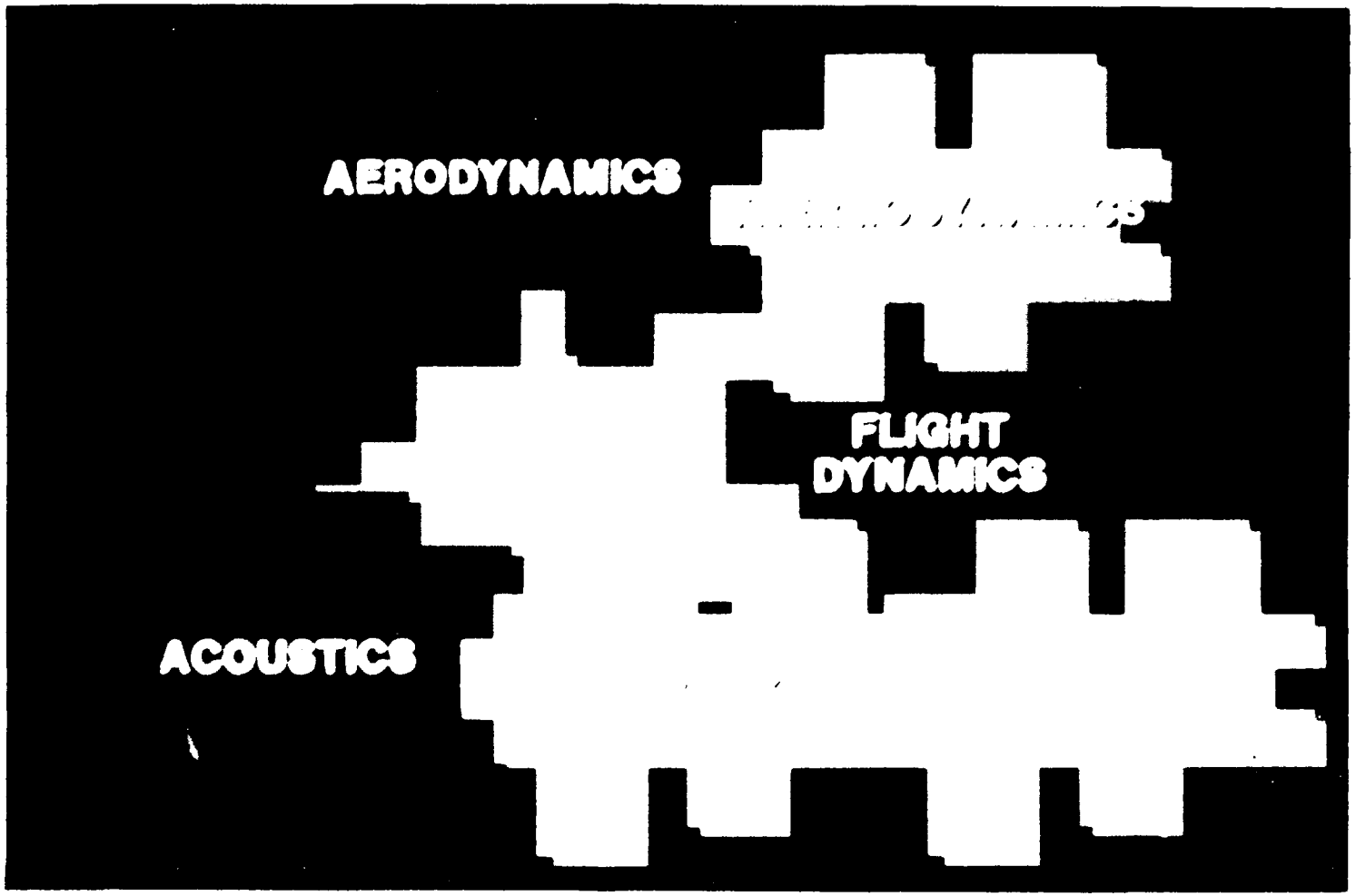
NICAD★

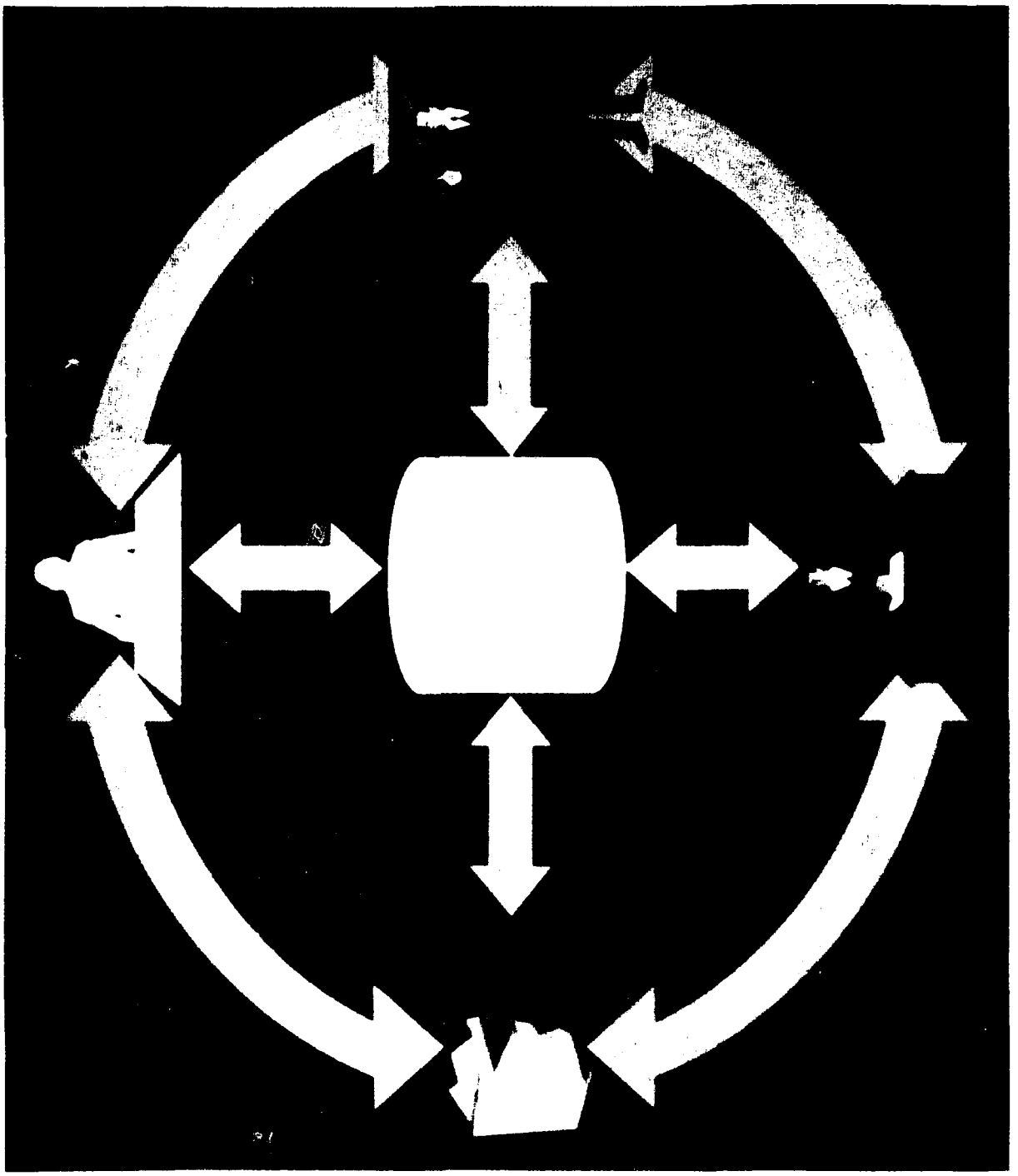
A NAVAIR RESOURCE FOR INCREASED PRODUCTIVITY

★ NAVAIR INTEGRATED COMPUTER-AIDED DESIGN

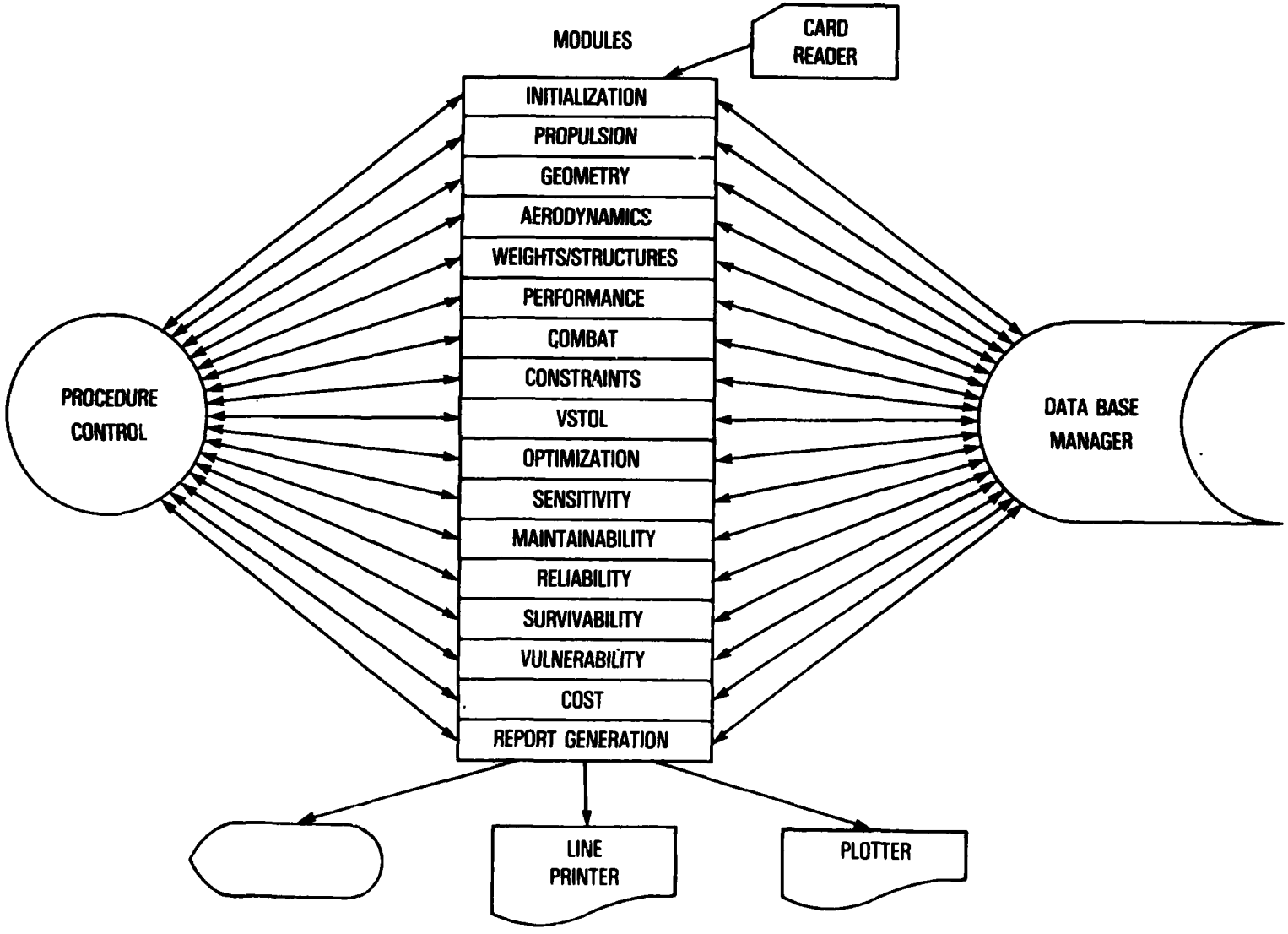

NICAD
AIRCRAFT
NASP
MISSILES
RAMS
MIDAS
HELICOPTERS
2 GCHAS




AERODYNAMICS
FLIGHT
DYNAMICS
ACOUSTICS



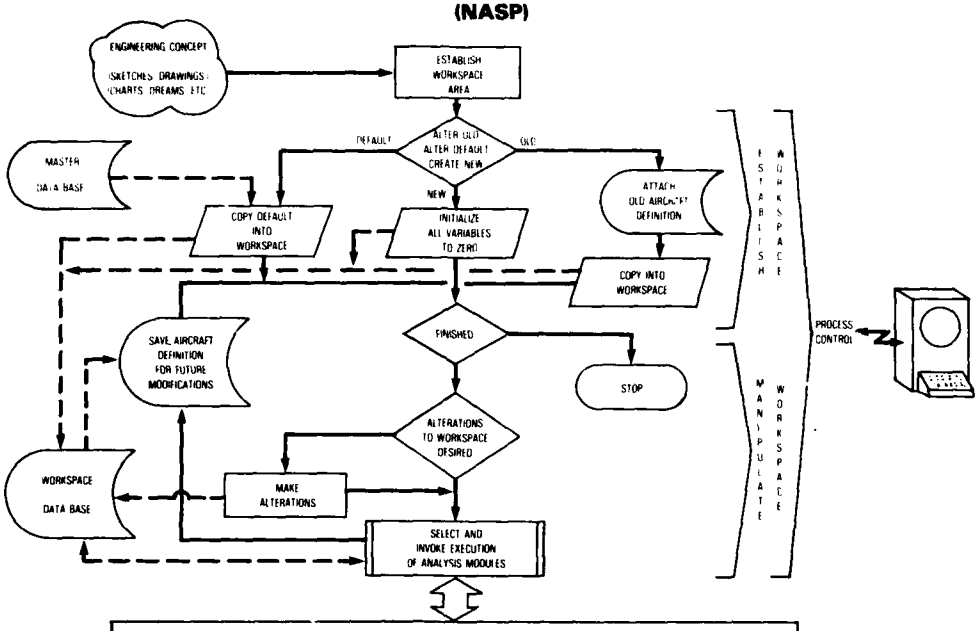
NAVAIR AIRCRAFT SYNTHESIS PROGRAM (NASP)



NASP PROGRAM

- MODULAR CONSTRUCTION
- EXTENSIVE DATA BASE
- ALL TECHNICAL DISCIPLINES INVOLVED
- TWO LEVEL OPERATING MODE
- BASED ON EXISTING PROGRAMS
  - LTV (ASCAP)
  - GD (VDEP)
  - NASA (ACSYNT)
  - ROCKWELL (CDS)
- DYNAMIC PROGRAM
  - EASY TO CHANGE
  - VERY READABLE

NAVAIR AIRCRAFT SYNTHESIS PROGRAM (NASP)



PRELIMINARY ASSESSMENT • DOMAIN SELECTION • ROUGH CALCULATIONS • TEST REASONABLENESS	PROPULSION	GEOMETRY	AERODYNAMICS • DRAG TABLES • DRAG POLARS • EFFICIENCY TABLES A 528	WEIGHTS/BALANCES • ESTIMATE A/C WEIGHT • INERTIA DISTRIBUTION • LOCATE C.G. • VOLUME & AREA LIM A 528
STRUCTURAL LOADS A 528	PERFORMANCE • SIMULATE MISSION • SIMULATE MANEUVERS • FUEL CONSUMPTION • ALTERNATE MISSION CAPABILITIES • V (MAX) FOR COSTING A 528	CONSTRAINTS	FLYING QUALITIES	COMBAT EFFECTIVENESS
V/STOL	V/STOL FOOTPRINT		ALTERNATE FUELS	OPTIMIZATION
MAINTAINABILITY	RELIABILITY	SURVIVABILITY	VULNERABILITY	COST • R & D COSTS • PROCUREMENT COSTS • OPERATING & SUPPORT COSTS • LIFE CYCLE COSTS NACOM A 688

Q: ARE YOU GOING TO BUILD A NEW AIRCRAFT DEFINITION OR ARE YOU GOING TO USE AN EXISTING AIRCRAFT DEFINITION?

BUILD-THIS ALLOWS YOU TO BUILD A NEW AIRCRAFT DEFINITION. YOU MAY USE A SPECIFIC AIRCRAFT DEFINITION, THE SYSTEM DEFAULT, OR YOU MAY BUILD YOUR OWN.

EXIST-THIS ALLOWS YOU TO USE AN EXISTING AIRCRAFT DEFINITION.

A: BUILD

Q: WHAT TYPE OF AIRCRAFT ARE YOU GOING TO BUILD?

TYPE XS - THE SPECIFIC TYPE FROM THE SYSTEM DATA BASE IS USED.
DEFAULT - THE SYSTEM DEFAULT AIRCRAFT DEFINITION IS USED.
NULL - A NULL AIRCRAFT DEFINITION IS CREATED. THIS ALLOWS YOU TO CREATE YOUR OWN AIRCRAFT DEFINITION.
LI - THIS LISTS ALL THE POSSIBLE TYPES OF AIRCRAFT DEFINITIONS YOU CAN CHOOSE FROM.

A: LI
0000000002
THIS IS AN A-4 TEST AIRCRAFT

Q: YOU NOW HAVE AN AIRCRAFT DEFINITION TO ANALZYE.
WHAT UPDATE FUNCTION DO YOU WANT TO PERFORM AGAINST YOUR AIRCRAFT DEFINITION?

MERGE - ALLOWS YOU TO REPLACE ANY DATA GROUPS IN YOUR AIRCRAFT DEFINITION FROM ANOTHER AIRCRAFT DEFINITION.
GRPCHG - ALLOWS YOU TO REPLACE ANY DATA GROUP IN YOUR AIRCRAFT DEFINITION FROM THE SYSTEM DATA BASE.
VARGHG - ALLOWS YOU TO REPLACE ANY DATA ELEMENT WITH A NEW VALUE.
END - TERMINATE THIS COMMAND.

- DEFINE THREAT
- TIME PERIOD
- RETALIATORY SYSTEMS
- SYSTEM REQUIREMENTS
- MISSION EQUIPMENT
- MISSION PROFILE & CONSTRAINTS

(1)

VIEW THREAT/SELECT RETALIATORY SYSTEM

MISSION EQUIPMENT

SYSTEM REQUIREMENTS

MISSION OPERATIONAL FUNCTIONS

- DOMINATE SPECIFIED AIRSPACE
- INTERDICT ENEMY FORCE/LINES
- SUPPORT GROUND ARTILLERY

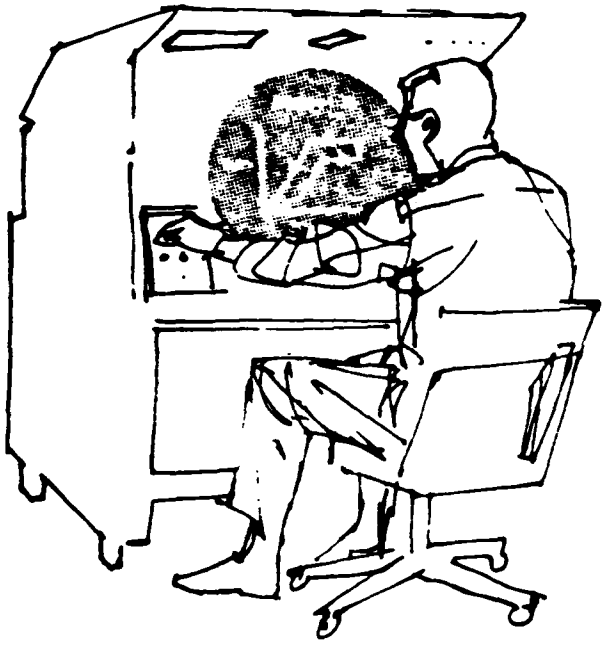
FUNCTIONAL DESTRUCT ROLES

- AIR-AIR DOG FIGHT
- AIR-AIR GROUND STRIKE

RANGE _____
MACH NO. _____
ALTITUDE _____

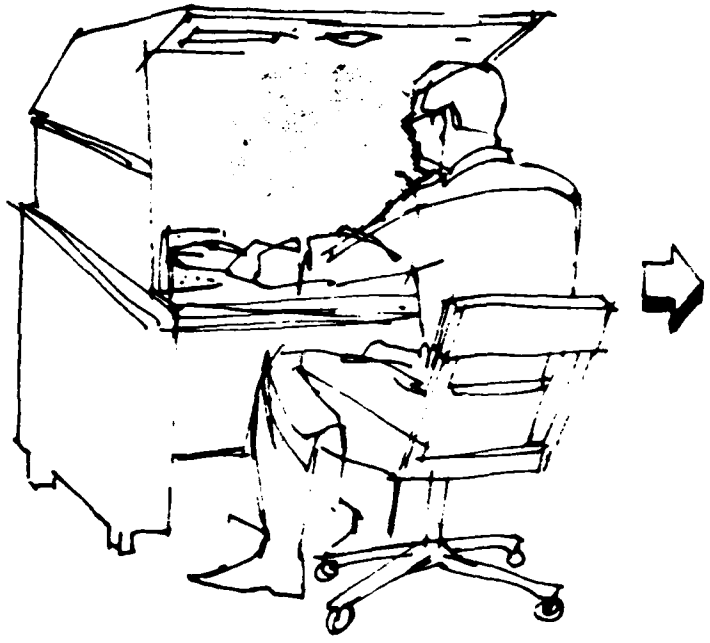
CANNON _____
AIR-AIR MISSILE _____
AIR-GROUND MISSILE _____

① MISSION DEFINITION



- DEFINE THREAT
- TIME PERIOD
- RETALIATORY SYSTEM
- SYSTEM REQUIREMENTS
- MISSION EQUIPMENT
- MISSION PROFILE & CONSTRAINTS

② SELECT CONFIGURATION PARAMETERS & SYNTHESIZE



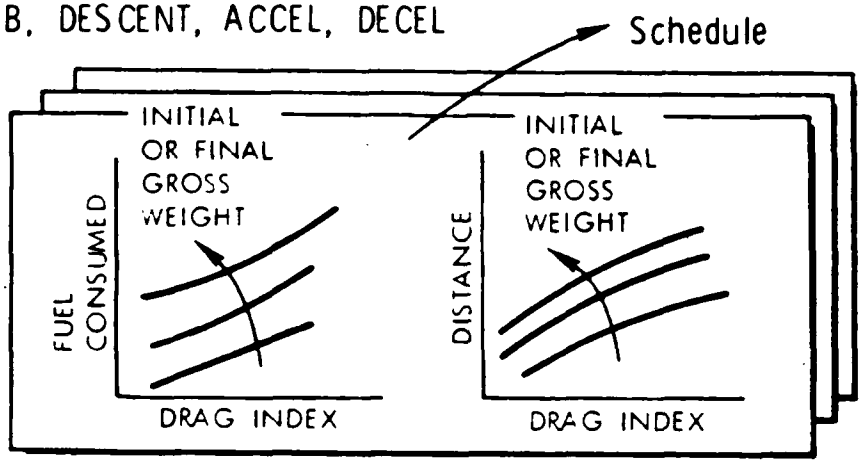
SYNTHESIS

- GEOMETRY
- MASS PROPERTIES
- AERODYNAMICS
- PROPULSION
- STRUCTURES
- ACCELERATION LIMITS

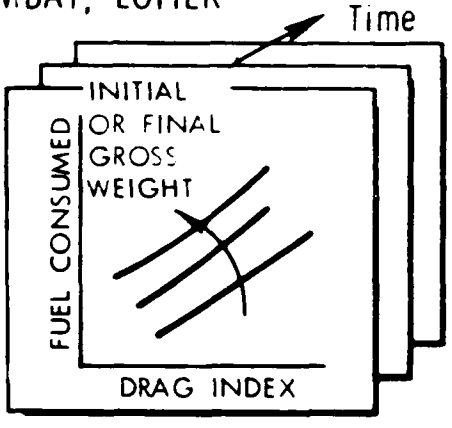
STANDARD MISSION SEGMENTS

- TAKEOFF
- LANDING
- DROP
- CRUISE
- DASH
- COMBAT
- LOITER
- CLIMB
- DESCENT
- ACCELERATION
- DECELERATION
- REFUEL

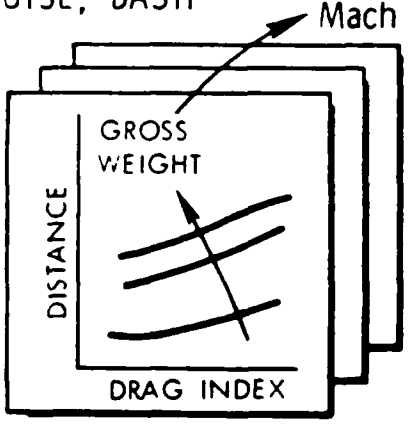
CLIMB, DESCENT, ACCEL, DECEL



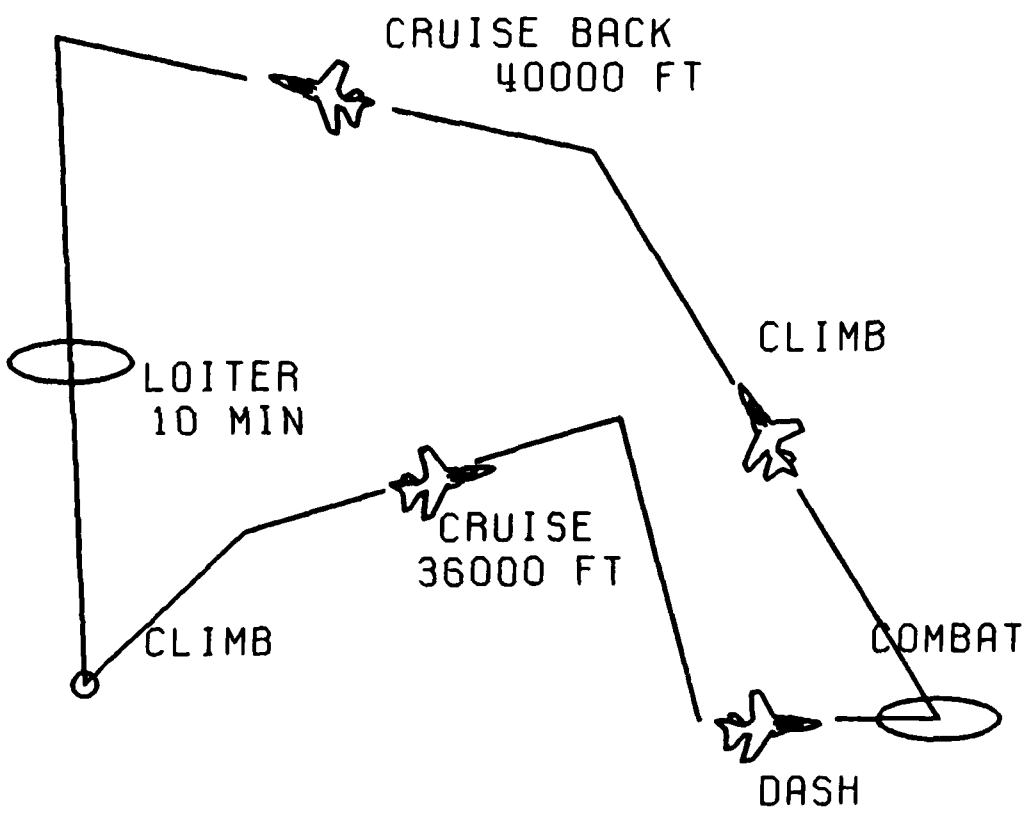
COMBAT, LOITER

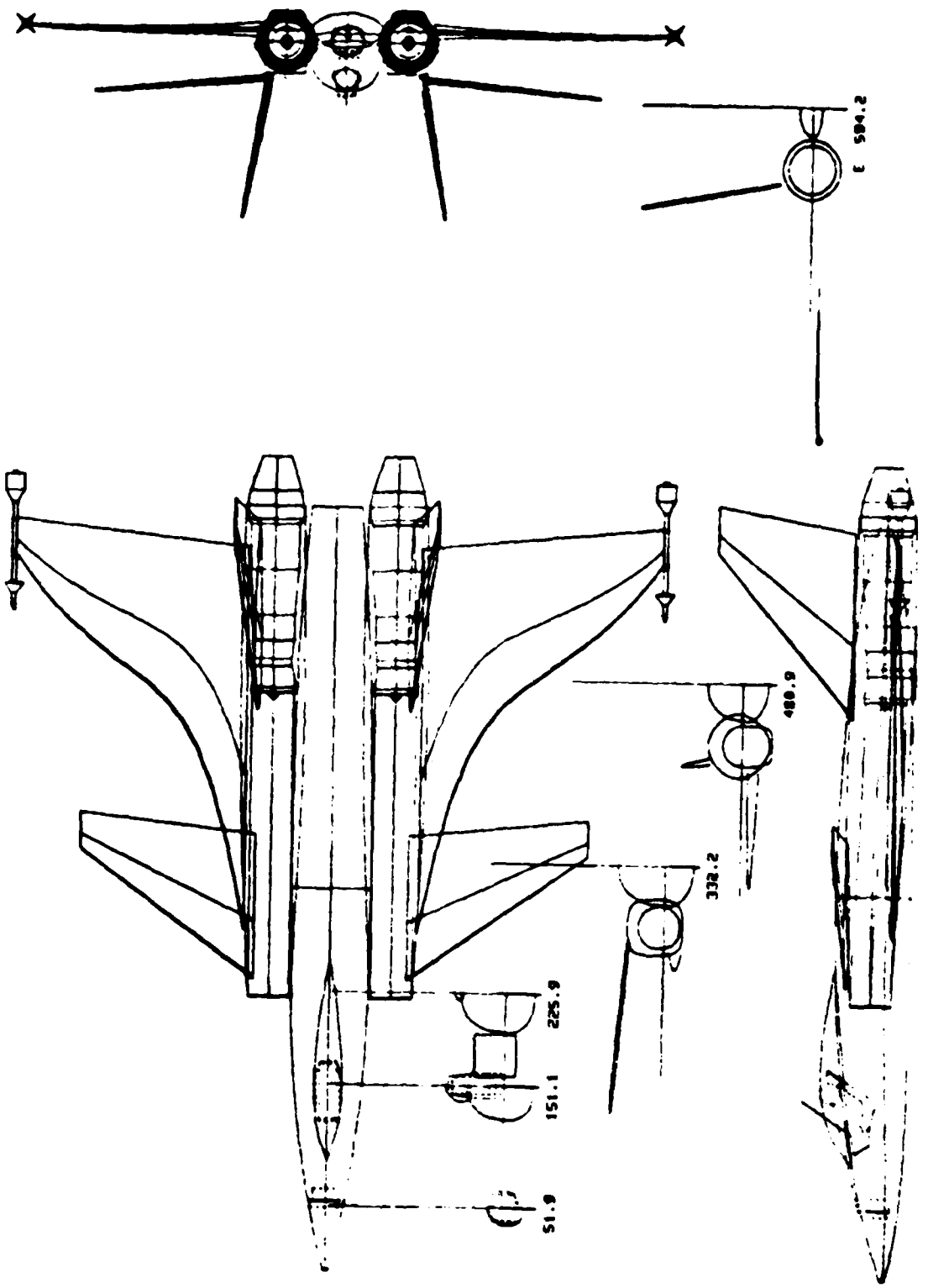


CRUISE, DASH

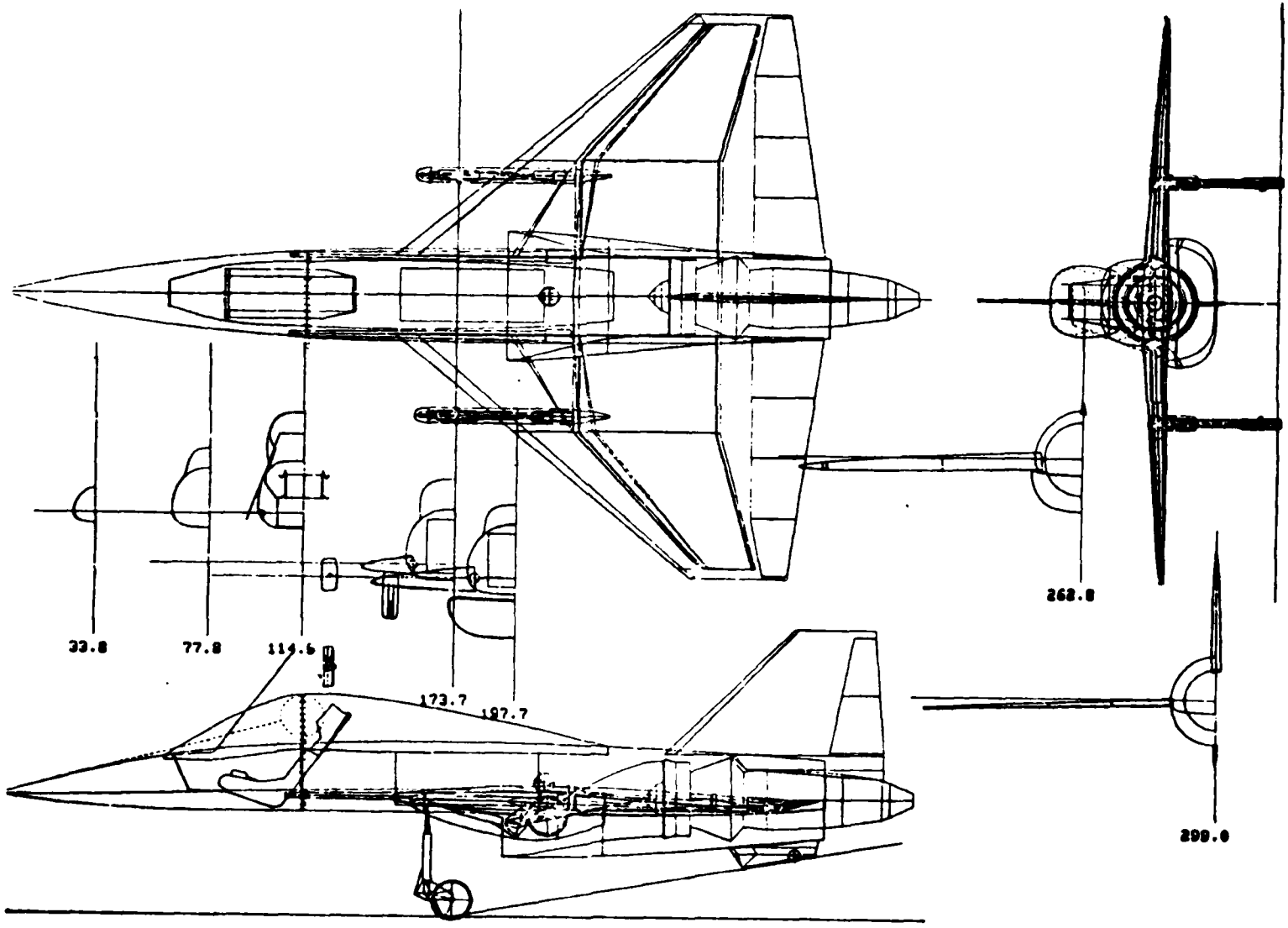


DESIGN MISSION PROFILE

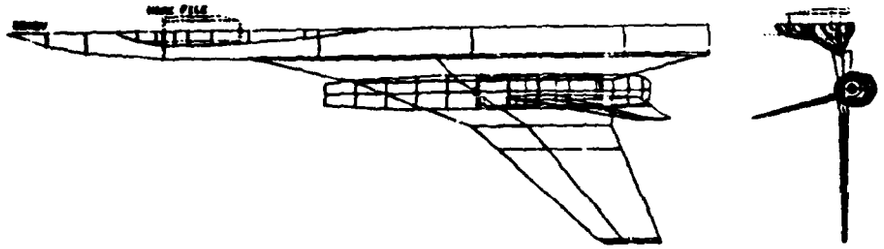


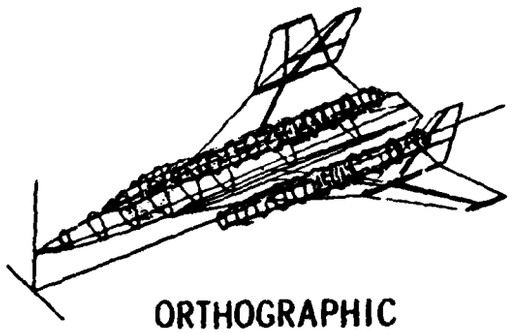

584.2
488.9
332.2
225.9
151.1
51.9

3-VIEW WITH SECTIONS



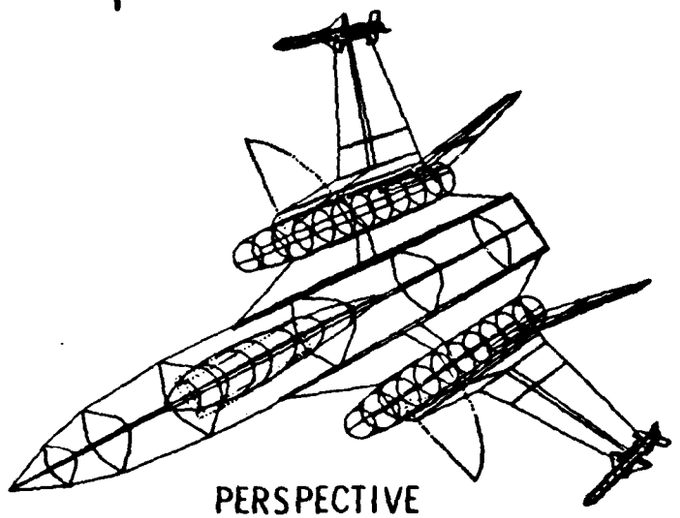
DISPLAY OPTIONS





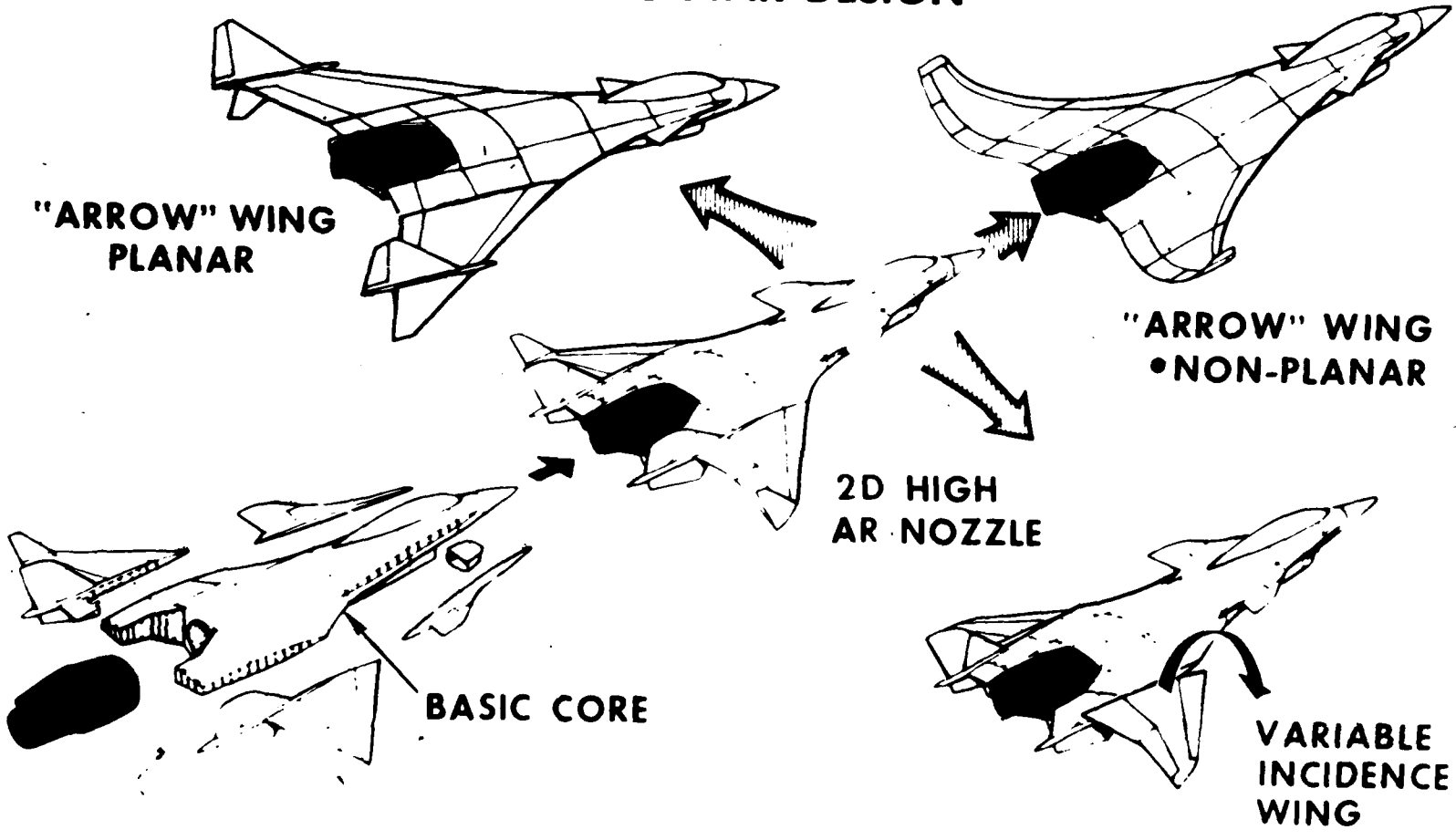
ORTHOGRAPHIC

THREE - VIEW



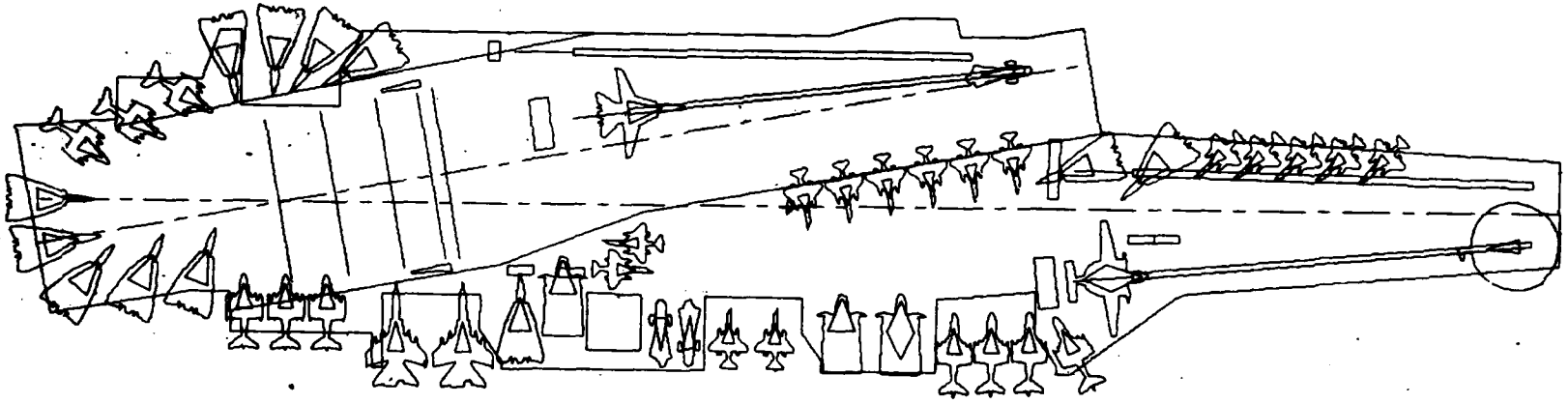
PERSPECTIVE

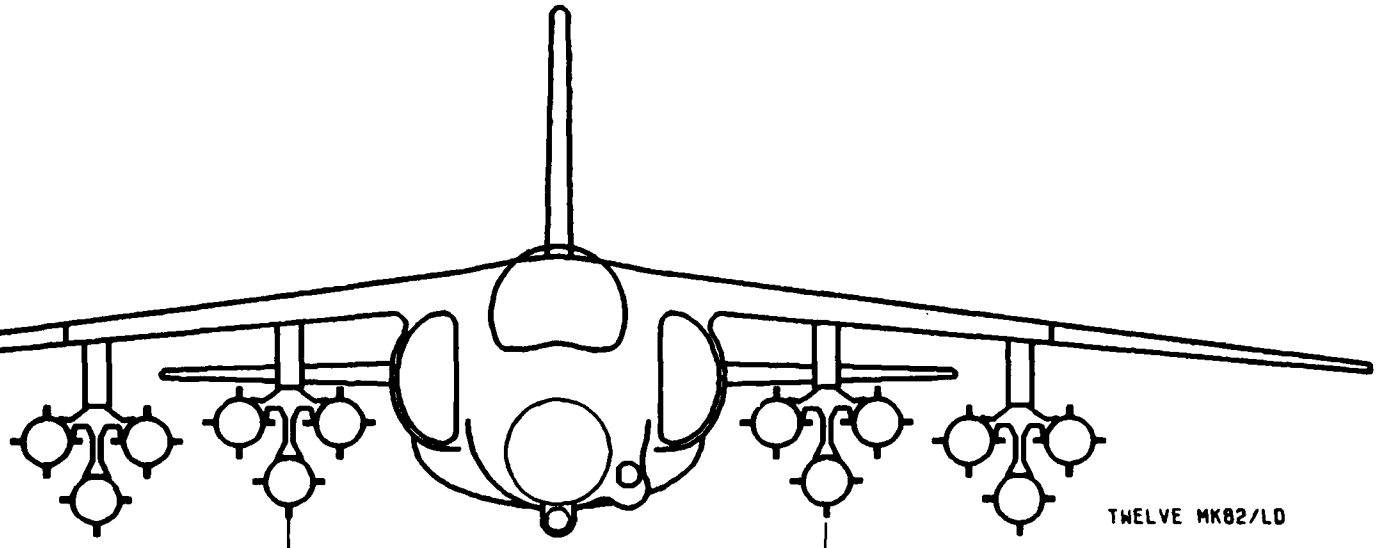
RESEARCH FUTURE POTENTIAL
MODULAR DESIGN



LOW-COST FLIGHT RESEARCH "TOOL" BRIDGING GAP BETWEEN WIND TUNNEL
& INCREASINGLY EXPENSIVE MANNED FLIGHT TEST

CVA FLIGHT ENTERPRISE · CVAN 65





TWELVE MK82/LD

TYPICAL LOADING

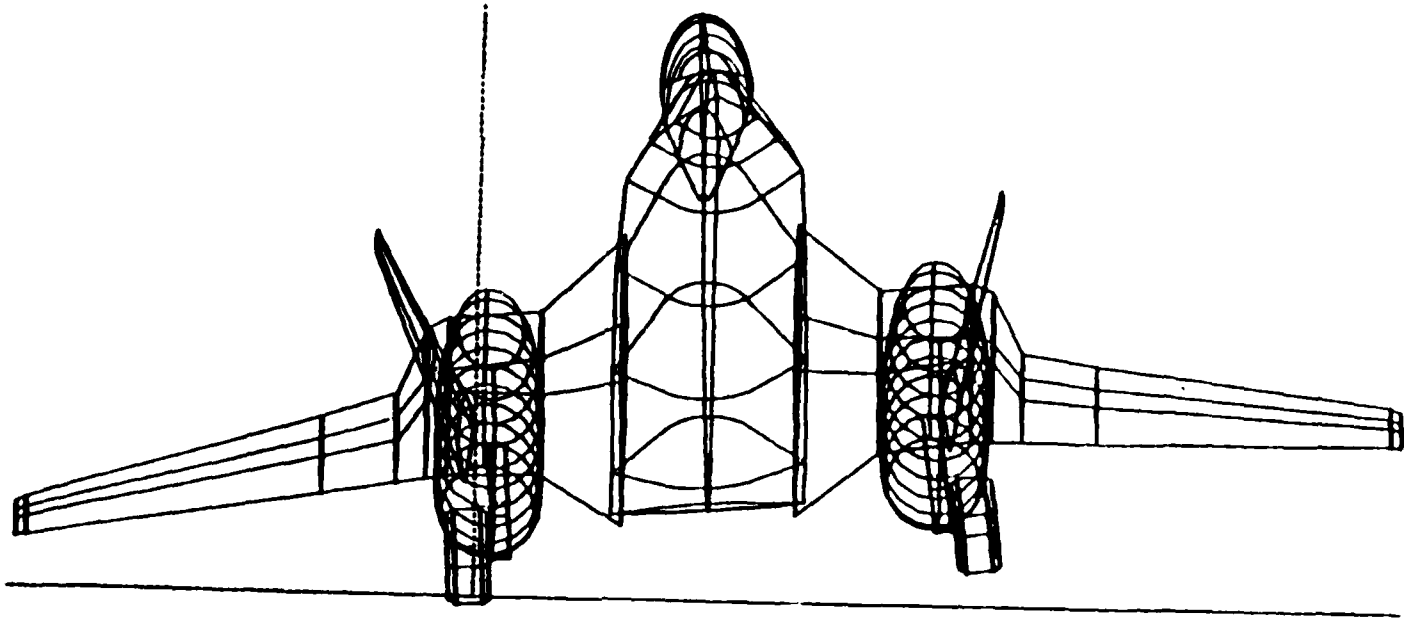
TWO 500 GALLON TANKS

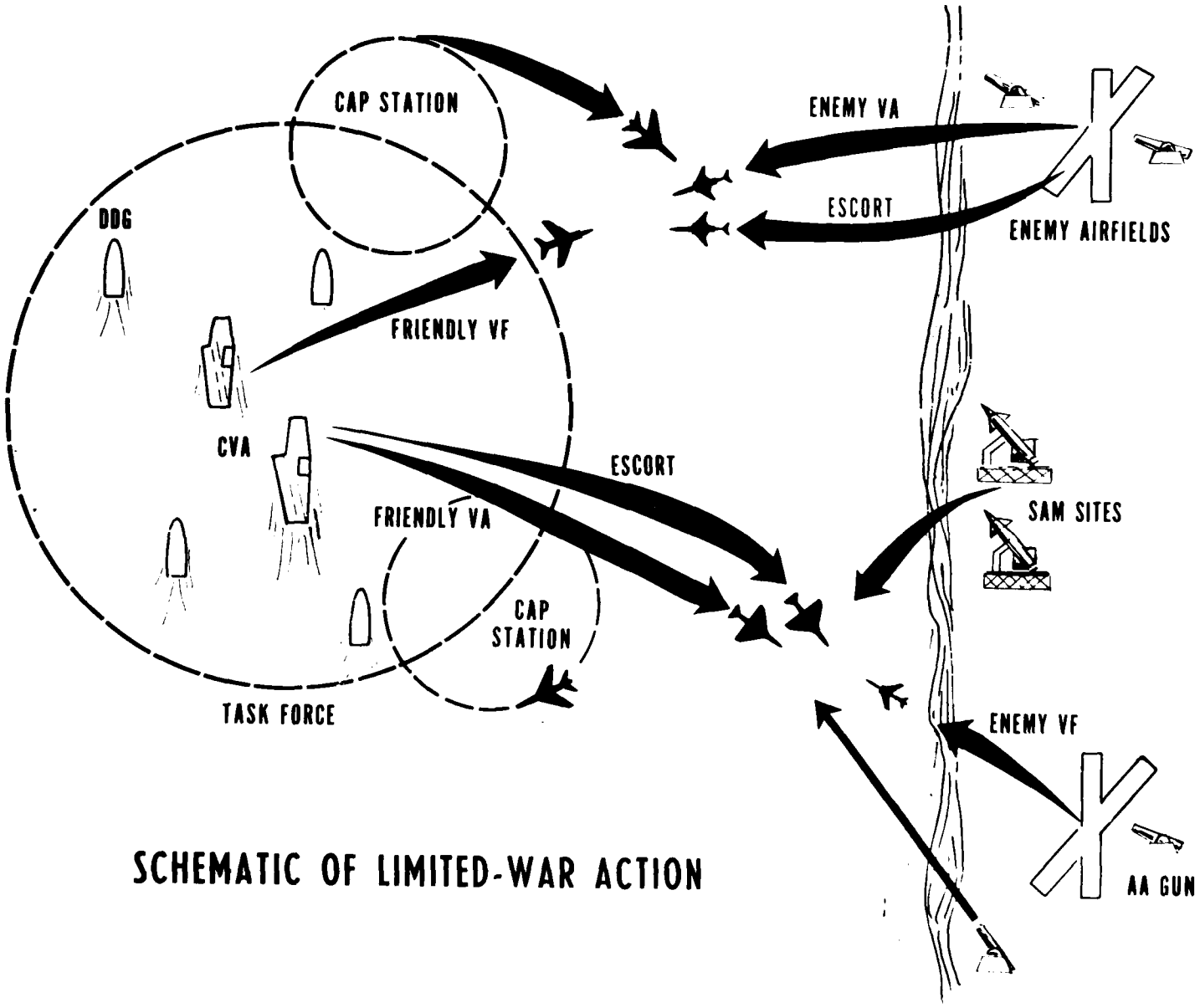
FOUR AIR-AIR

MATCHING OF WINDTUNNEL JETTISON CASE 1399 AT AIT

GROUND CLEARANCES

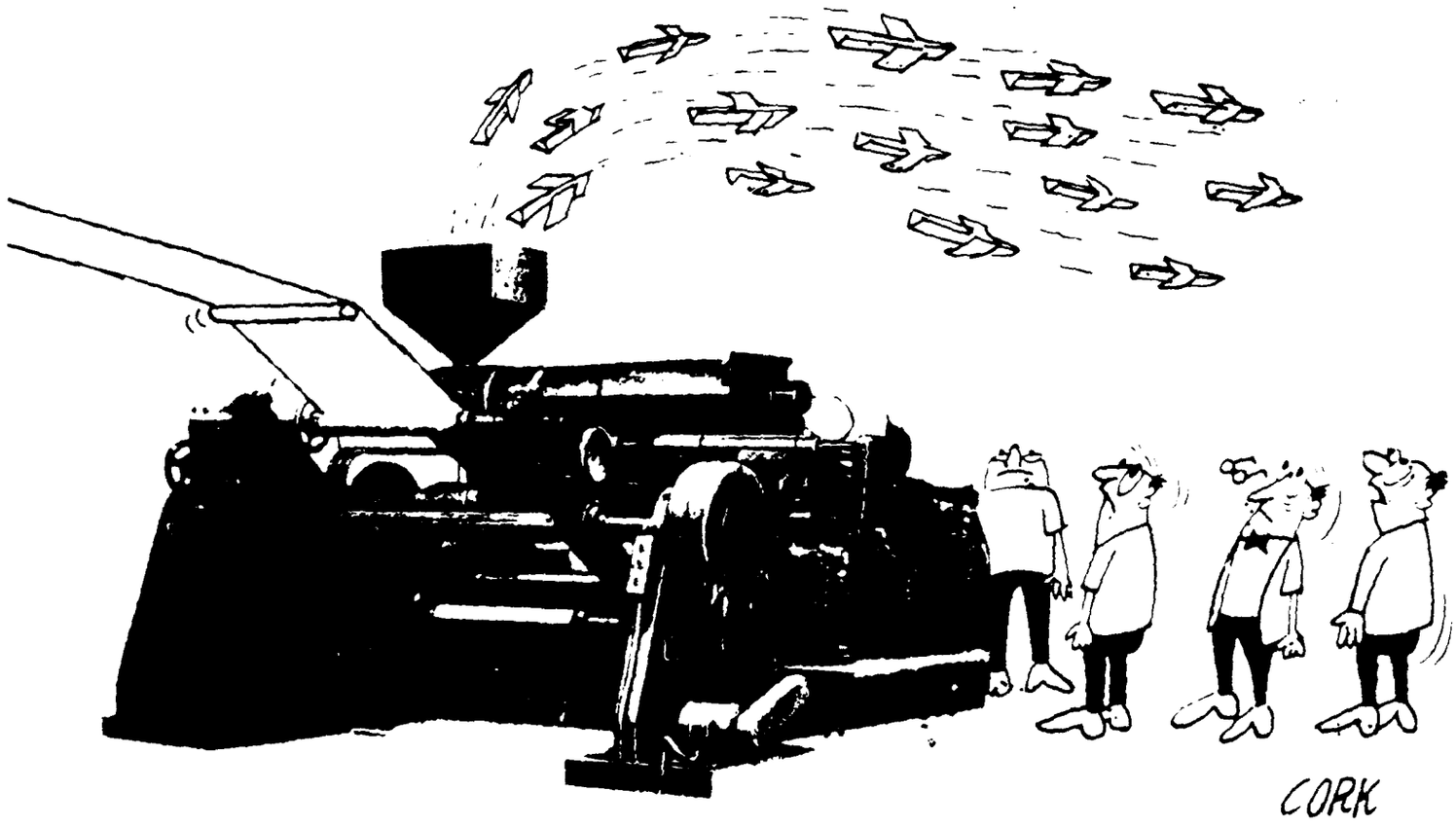
- MAX TAIL DOWN
- 5° ROLL
- STRUT & TIRE COMPRESSED

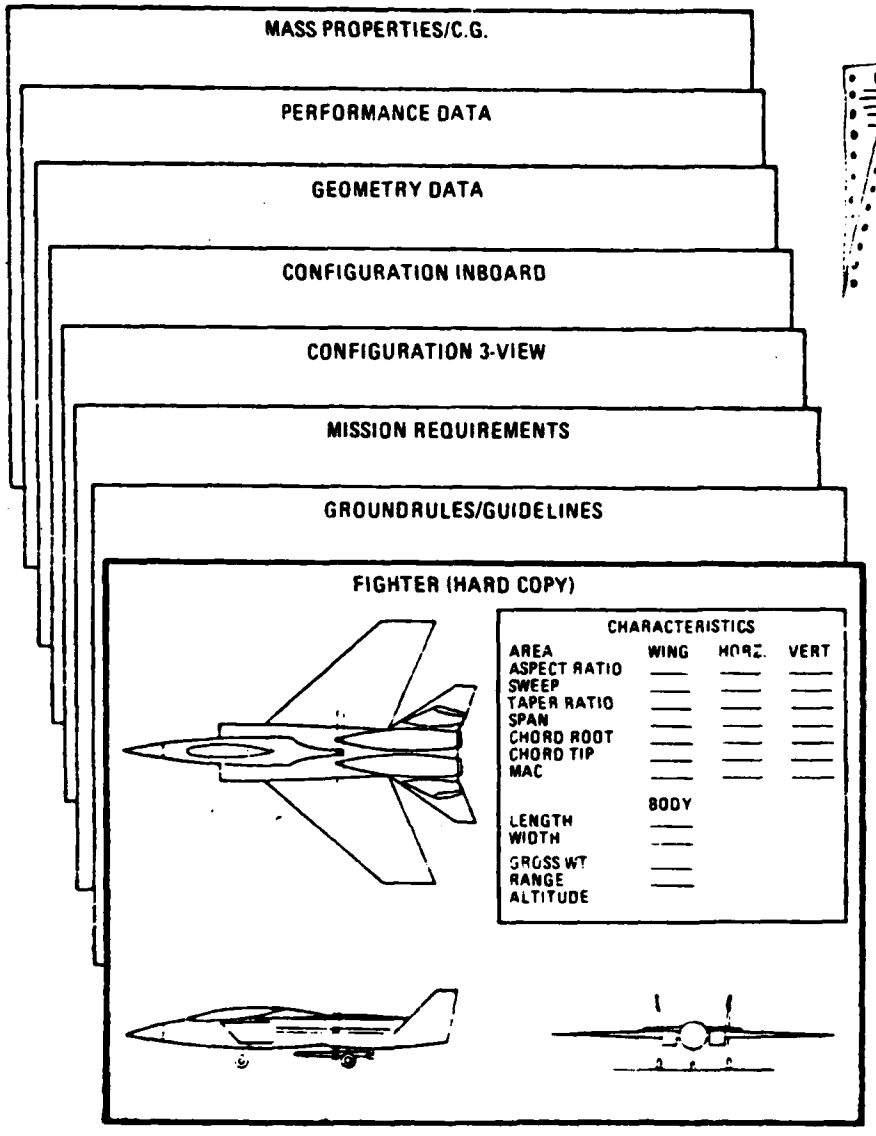


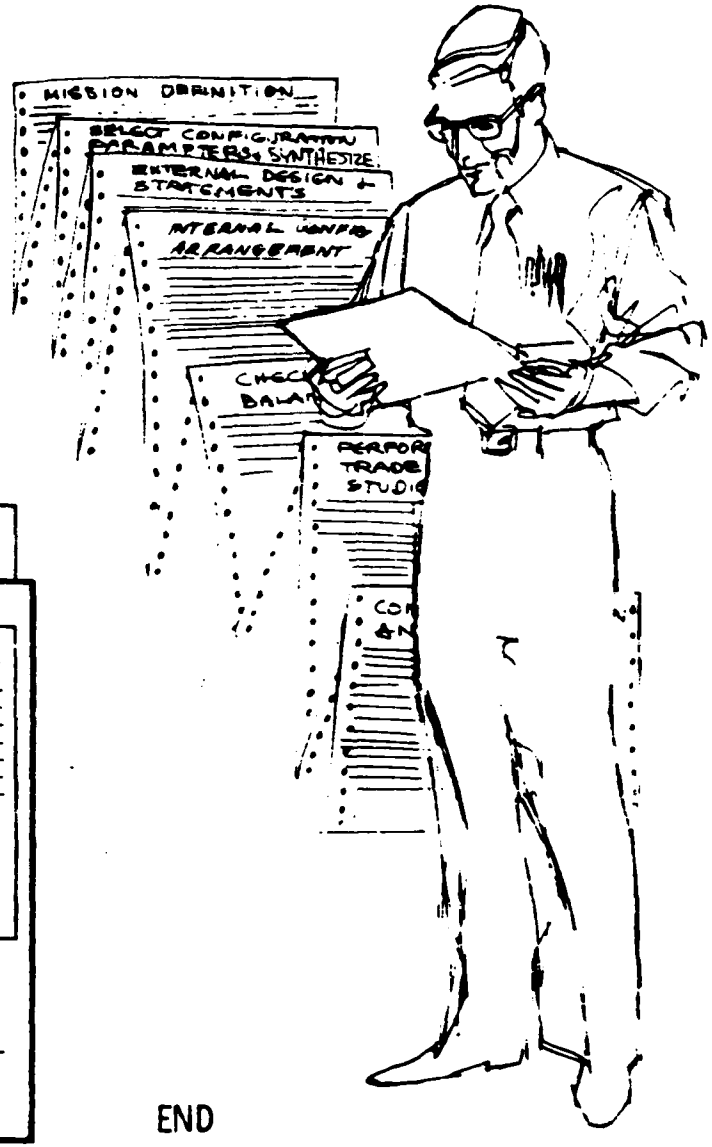


SCHEMATIC OF LIMITED-WAR ACTION

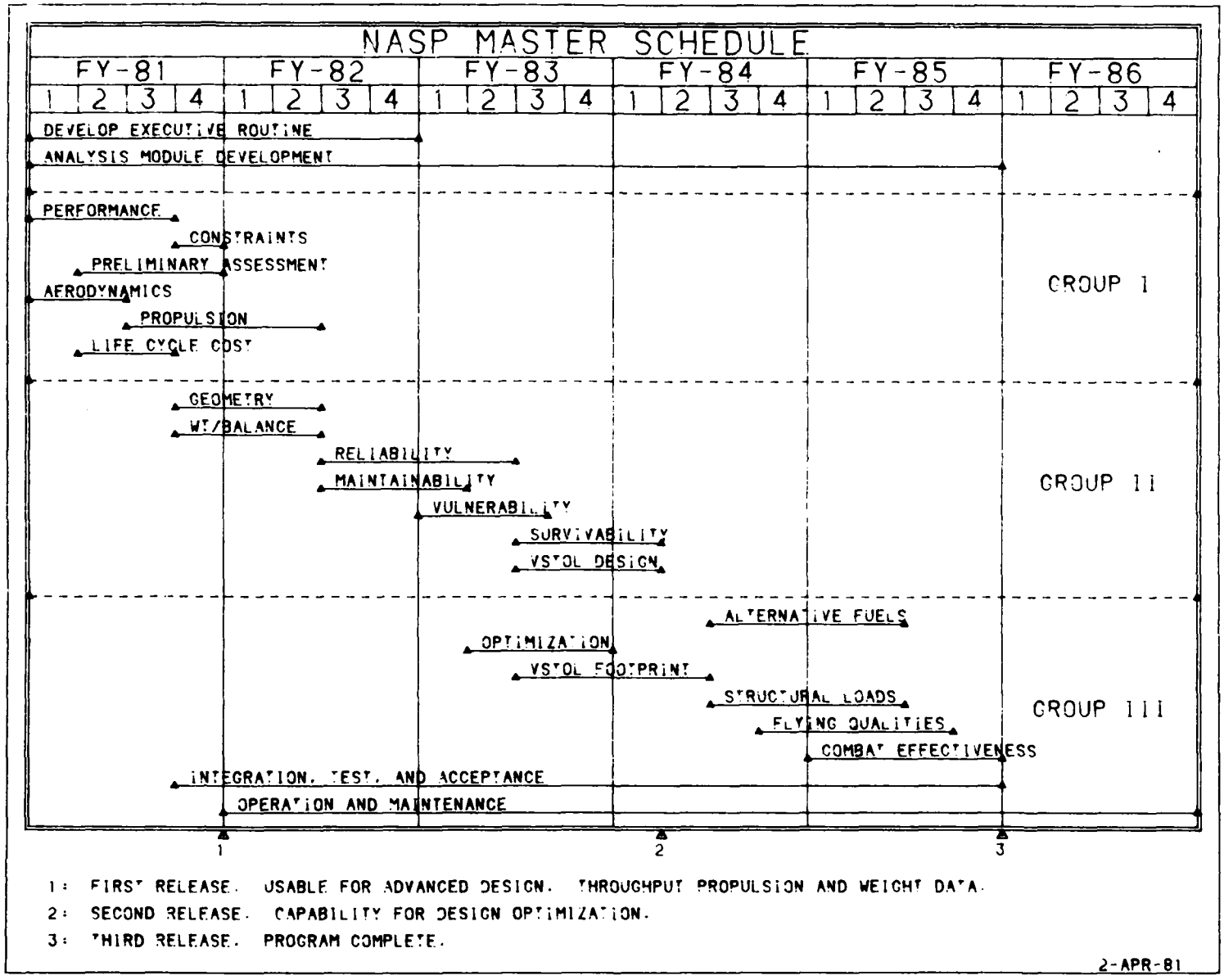
"PICK ONE"




MASS PROPERTIES/C.G.
PERFORMANCE DATA
GEOMETRY DATA
CONFIGURATION INBOARD
CONFIGURATION 3-VIEW
MISSION REQUIREMENTS
GROUNDRULES/GUIDELINES
FIGHTER (HARD COPY)
CHARACTERISTICS
AREA
ASPECT RATIO
SWEEP
TAPER RATIO
SPAN
CHORD ROOT
CHORD TIP
MAC
WING
HORZ.
VERT
BODY
LENGTH
WIDTH
GROSS WT
RANGE
ALTITUDE


MISSION DEFINITION
SELECT CONFIGURATION
PARAMETERS SYNTHESIZE
EXTERNAL DESIGN
STATEMENTS
INTERNAL
ARRANGEMENT

END



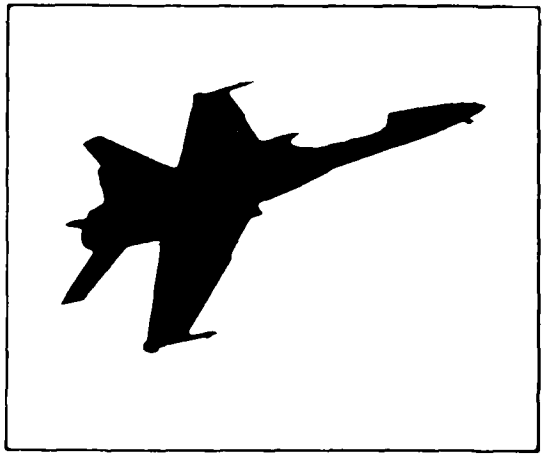
1: FIRST RELEASE. USABLE FOR ADVANCED DESIGN. THROUGHPUT PROPULSION AND WEIGHT DATA.

2: SECOND RELEASE. CAPABILITY FOR DESIGN OPTIMIZATION.

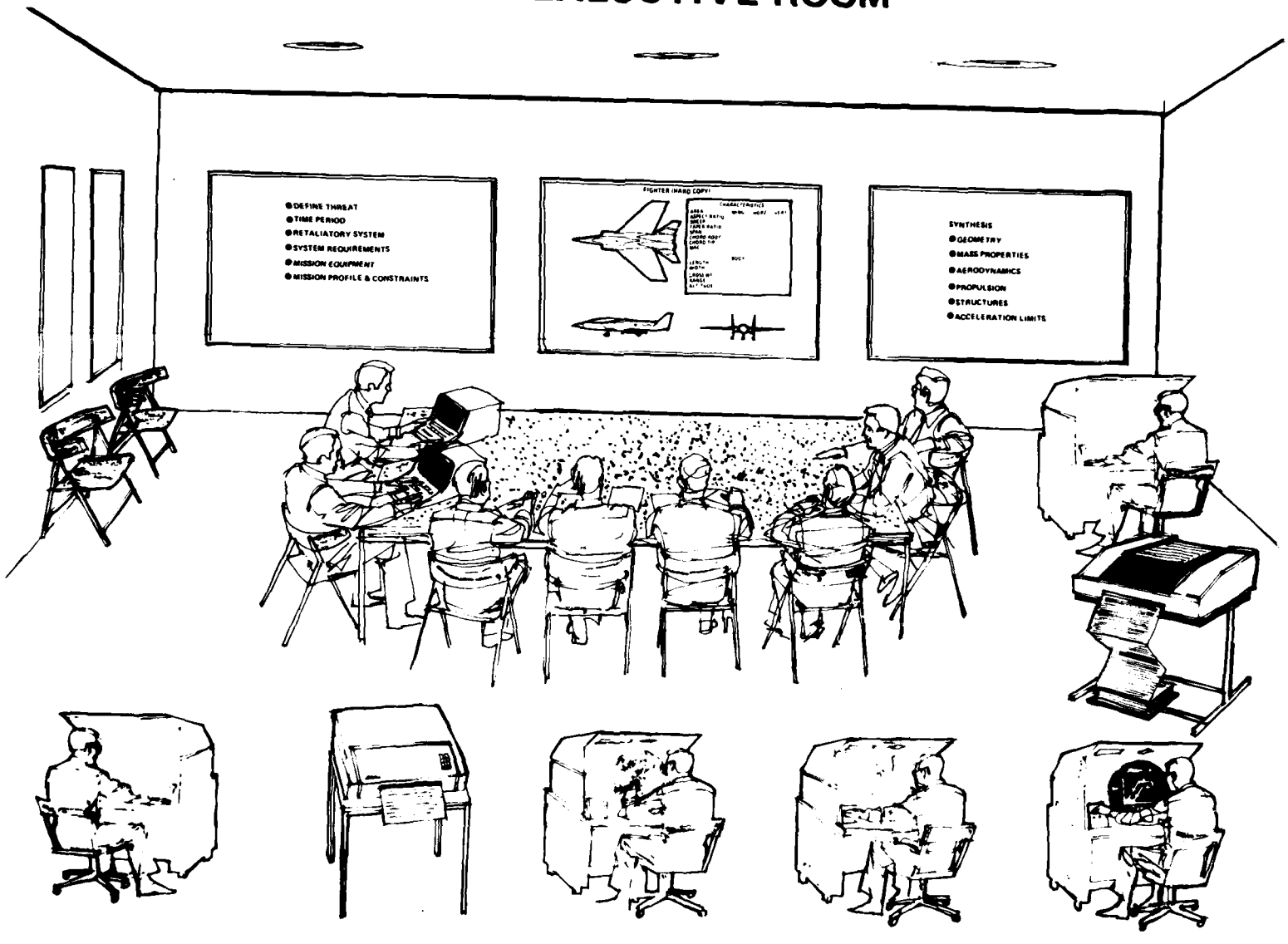
3: THIRD RELEASE. PROGRAM COMPLETE.

2-APR-81

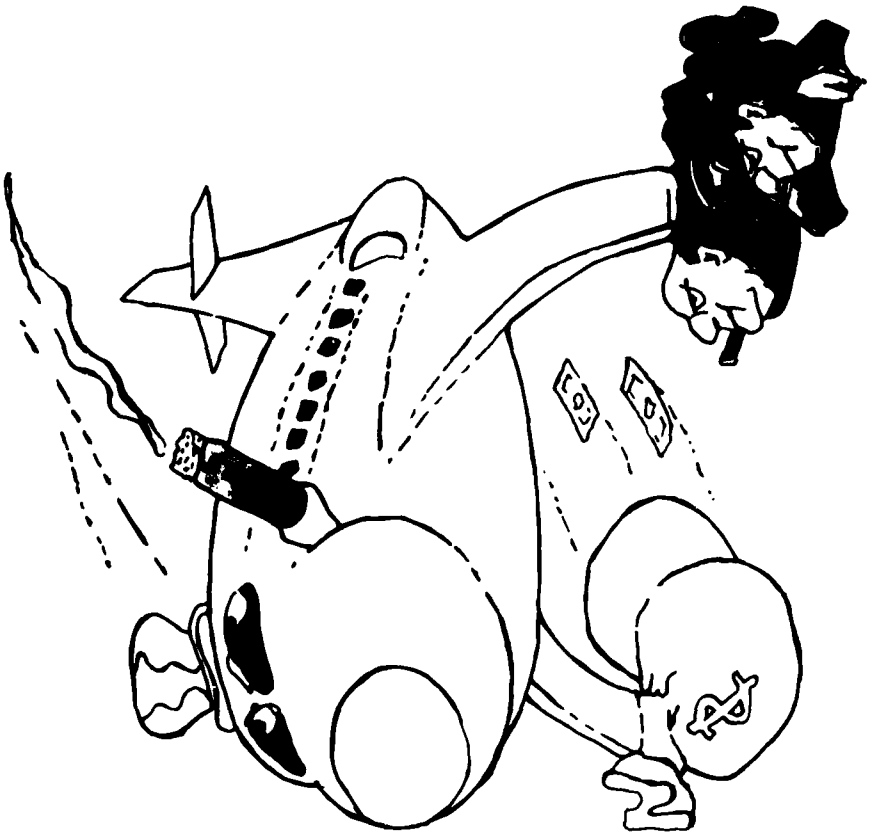
BASELINE



EXECUTIVE ROOM



06033CVD5866



COMPUTER GRAPHICS IN THE ADVANCED CONFIGURATION DESIGN & ANALYSIS PROCESS

T.J. Weir
Northrop Aircraft Division
Hawthorne, California

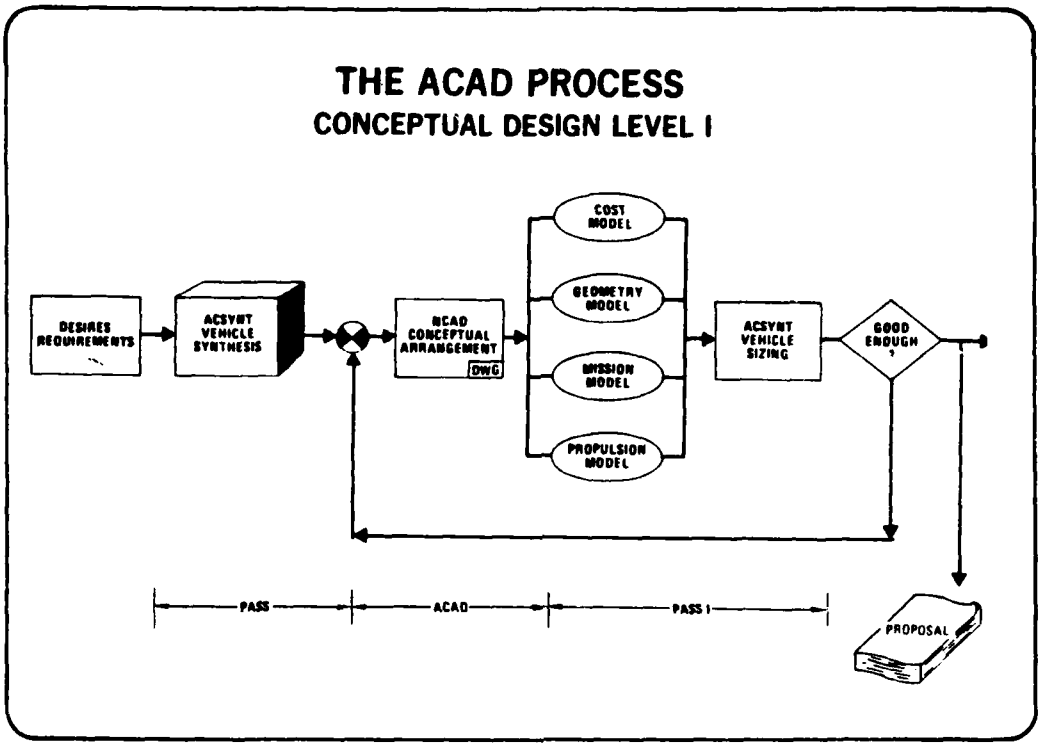
COMPUTER GRAPHICS IN THE ADVANCED CONFIGURATION DESIGN & ANALYSIS PROCESS

T.J. Weir
Northrop Aircraft Division
Hawthorne, California

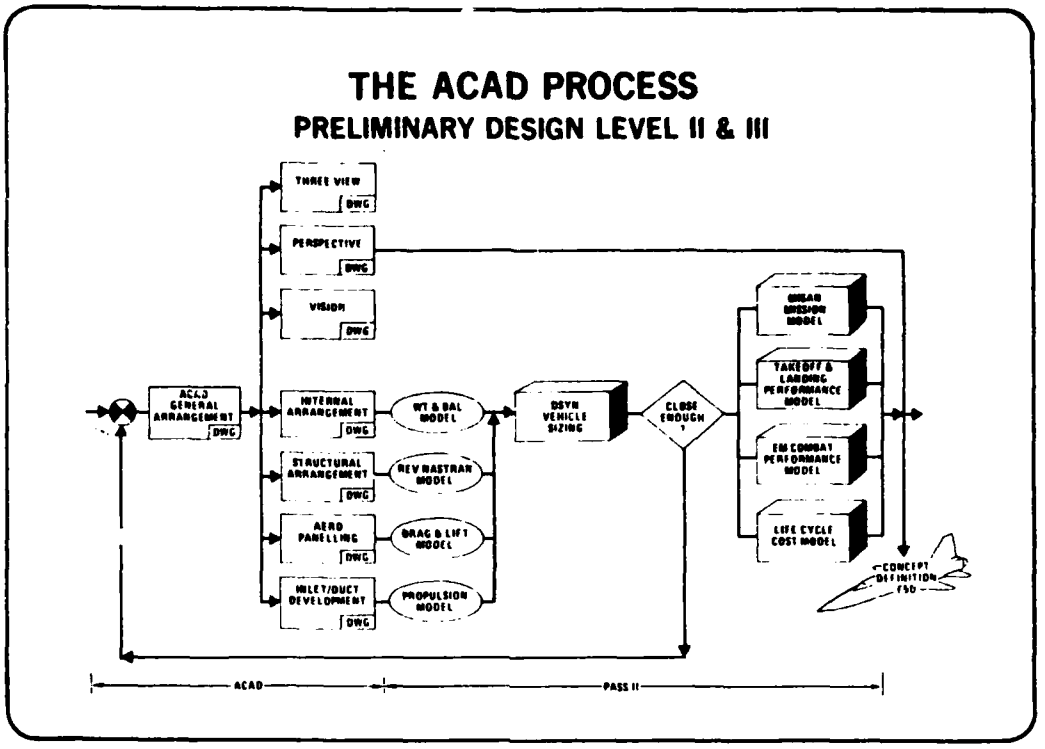
To meet the rigorous constraints imposed upon supersonic aircraft, the conceptual designer must mold and shape the entire configuration by iteratively locating critical components such as the engine, fuel bays, guns, radar, and crew stations and then drawing accurate, smooth body control lines and many section cuts to assure adequate clearances and a proper cross-sectional area distribution for minimum wave drag. Assuring proper aircraft balance, minimum weight, cockpit visibility, and landing gear placement for rotation clearance are but a few of the design considerations.

Manually drawn, smooth, accurate shapes are very time-consuming, cumbersome to construct and analyze, and painstaking to iterate. Through computer graphics' use of modular library components, rapid curve fit routines, and automatic section construction, the designer is given much relief from the rote task of mechanical construction and afforded more time to address the critical design integration functions. This paper presents the Northrop hardware/software system, Advanced Configuration Analysis and Design (ACAD) system, discusses techniques involved and concludes with some applications to aircraft survivability as inputs to signature and vulnerability models.

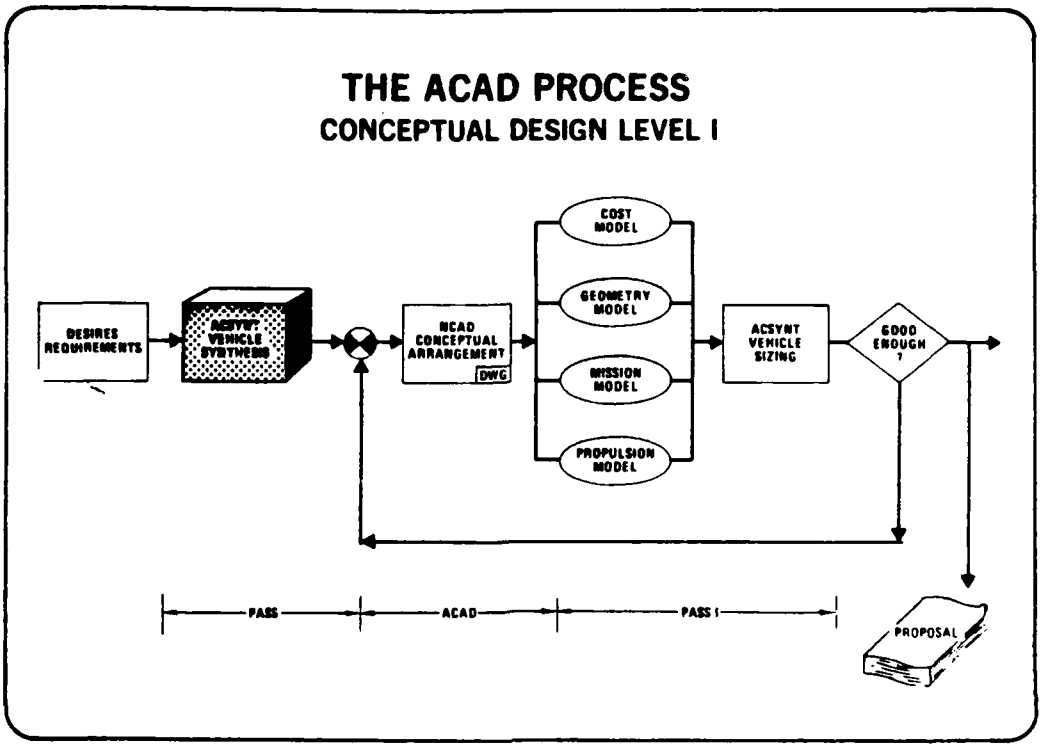
The problem-solving process is much like the chicken and egg dilemma: which came first? Whether a solution is synthesized to meet a problem or whether the problem is analyzed to produce a solution is a somewhat moot question. For the purpose of this paper, let me define the synthesis process as starting with a blank piece of paper and developing a solution to a problem. This is contrasted with the analysis process wherein the analyst is given a baseline approach, and proceeds to analyze its capability to solve the problem. Many computer design packages tend to start with the analysis loop, where mission requirements, etc., are fed into one end of the computer and a "synthesized" configuration comes out the other end. The ACAD process starts with a vehicle synthesis or design and then proceeds to the analysis.



The design process as defined by ACAD covers the first two phases or levels of the Aircraft Design process; conceptual design, and preliminary design. The design process starts with a vehicle synthesis or design and then proceeds to the analysis. This is not the only approach to the problem, rather, it is the way that the conceptual design process has evolved at Northrop and represents a logical extension of the design approach using new tools.



The preliminary design phase consists of a more detailed definition of the vehicle followed by a multi-disciplined examination and analysis to determine the validity of the design. This process requires significant data generation, computation, and design iterations as the design evolves. By the use of computer graphics and computer generated data sets, this process is made more rapid and accurate.



The first step in the Design Process is to synthesize a concept that satisfies specified requirements such as: mission radius, payload, takeoff and landing distances, operating altitude and speed, and combat turn and acceleration performance. The ACSYNT program presented here is a vehicle synthesis program developed by NASA and now being utilized by Northrop. This program is very flexible in that it can compute widely differing vehicles from large transports to small fighters. By the specification of certain constraints many different solutions may be obtained from the same set of requirements.

ACSYNT INPUT DATA

```
                                INITIAL WEIGHTS INPUT DATA
                                ACSYNT MODULE NUMBER 6
                                MODULE VERSION  4-76
AIRCRAFT TYPE:  FIGHTER
TITLE:              TEST AIRCRAFT WEIGHTS (DEFAULT

CONTROL OPTIONS

    IPRINT =  1   IGRAPH =  1   ITAIL  =  0   KERROR =  0
    IDELT  =  0   IDBLIQ =  0   KWING  =  1   KBODY  =  1
    K1     = 1.00 K2     = 1.00 K3     =  1.0 K4     =  1.0
    K5     = 1.00 K6     = 1.00 KFMACH = 0.0  MAXIT  =  1
    K8     = 0.0  KP1    = 0.0  KP2    = 0.0
    FR     = 1.50 TECHG  = 1.00 WGTO   =    26000.
    STRESS =    30000.          DENS   =  0.056     PLIFTF =0.0
    TECHI  =  1.00  1.00  1.00  1.00  1.00  1.00  1.00  1.00  1.00
  SLOPE(1) =  1.00  1.00  1.00  1.00  1.00  1.00  1.00  1.00  1.00
  SLOPE(9) =  1.00  1.00  1.00  1.00  1.00  1.00  1.00  1.00  1.00

INITIAL ESTIMATES
 IF CODE = 1, WEIGHT IS FIXED

 QUANTITY       VALUE   CODE          QUANTITY       VALUE   CODE

  WAP    =      7824.   0             WAIRC  =       260.   1
  WAPU   =         0.   0             WAMMUN =       288.   1
  WARM   =        70.   1             WHAG   =         0.   0
  WBBI   =         0.   0             WBODY  =      2821.   1
  WCAND  =         0.   0             WCARGO =         0.   0
  WCREW  =       215.   1             WE     =      5632.   1
  WELT   =       910.   1             WEP    =       645.   1
  WETANK =         0.   0             WFEQ   =      3599.   0
  WFS    =       695.   1             WCA    =       730.   0
  WGEAR  =        78.   0             WHOP   =      1290.   1
  WHT    =       370.   1             WINST  =       120.   1
  WLG    =       730.   1             WMISS  =         0.   0
  WNA    =       261.   0             WPA    =         0.   0
  WPASS  =         0.   0             WPL    =      3104.   0
  WPS    =      3599.   0             WSC    =       645.   1
  WTSUM  =     26000.   1             WVT    =       141.   1
  WWING  =      1806.   1             WBOMB  =       960.   1
  WENVP  =         0.   0             WPIV   =         0.   0
  WLIFTF =         0.   0

   * * * BEGIN VEHICLE CONVERGENCE
```

This represents a print of input data which is used to define a solution vehicle. The ACSYNT program is set-up to run with logical defaults where all inputs are not specified. As few as sixteen inputs have been used to derive solutions. These solutions have shown good agreement with more defined solutions which require over a thousand inputs.

ACSYNT MISSION DATA

TRAJECTORY INPUT

TIMTO1 = 5.0	MENOUR = 1.	NCRUSE = 2	IPLOT = 0				
TIMTO2 = 1.0	QMAX = 700.	IPSIZE = -2	HMINP = 0.				
FRFURE = 0.0	XDESC = 80.0	IPSTO1 = 5	HMAXP = 55000.				
DESLF = 8.00	WKFUEL = 1.000	IPSTO2 = 2	DELHP = 4000.				
ULTLF = 12.00	CRMACH = 1.600	IBREG = 0	SMMINP = 0.050				
RANGE = 250.	WRLAND = 0.570	IENDUR = 0	SMMAXP = 1.600				
WFUEL = 8334.	FLFAC = 0.400	IPRINT = 0	DELMP = 0.100				
WFEXT = 0.	WECEL = 0.250	KERROR = 2	WCOMSP = 0.04				
WFTRAP = 200.	NLEVCL = 0	NLEGCR = 0	NLEGLO = 0				
PWGMAX = 1.200	TOL = 0.001	MILCOM = 0	NMISS = 1				

MISSION 1

PHASE	MACH START	MACH END	ALT START	ALT END	MINIZ DIST	TIME	NO. TURNS	WIND WKFUEL	IP IPRT	IX IB	IW IA
CLIMB	0.40	0.95	500.	44000.	12.6	1.6	0.0	0.0	1	-1	0
								1.000	0	0	0
CLIMB	1.60	1.60	44000.	50000.	51.1	4.3	0.0	0.0	1	-1	0
								1.000	0	0	0
CRUISE	1.60	1.60	50000.	50000.	-1.0	0.0	0.0	0.0	4	1	0
								1.000	0	0	0
COMBAT	0.90	0.90	30000.	30000.	0.0	2.9	4.0	0.0	1	0	0
								1.000	0	0	0
COMBAT	1.20	1.20	30000.	30000.	0.0	1.6	2.0	0.0	1	0	0
								1.000	0	1	0
CRUISE	0.90	0.90	50000.	52000.	-1.0	0.0	0.0	0.0	4	1	0
								1.000	0	0	0
LOITER	0.40	0.90	0.	0.	0.0	22.0	0.0	0.0	4	0	0
								1.000	0	0	0

CALLING MODULE NUMBER 3

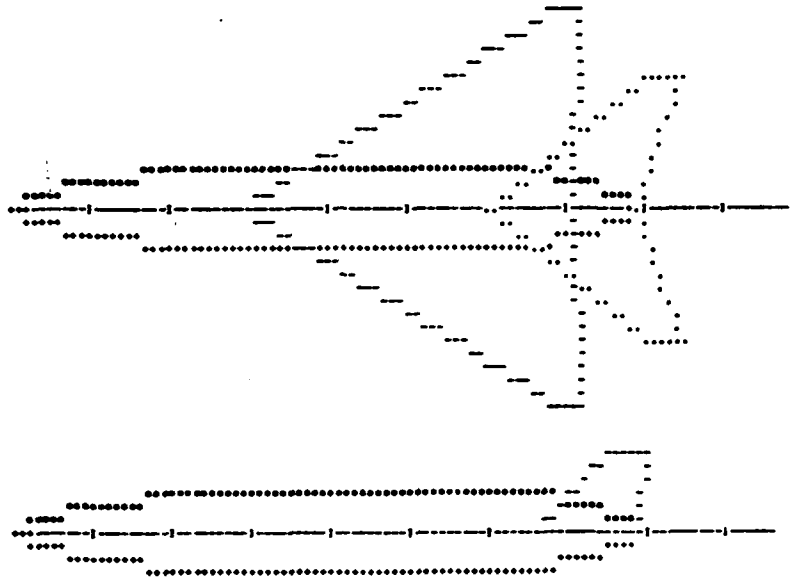
The mission can be described simply or in great detail depending on requirements and/or desires. Presented here is a sample imput of a typical fighter mission.

ACSYNT OUTPUT DATA

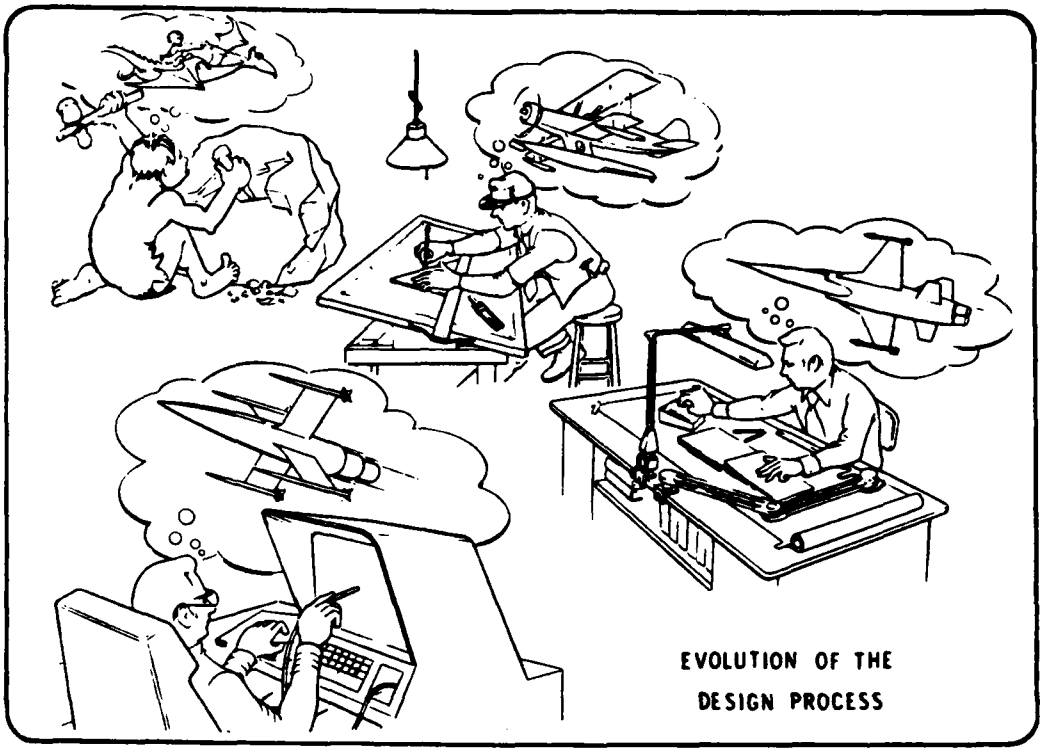
```
SUMMARY --- ACSYNT OUTPUT --- NASA, AMES RESEARCH CENTER

TEST AIRCRAFT CONVERGENCE (COPES)                                  10/01/80

GENERAL                FUSELAGE                          WING  HTAIL  VTAIL

WG      30799.   LENGTH          47.5   AREA           400.0  141.7   33.5
W/S       76.9   DIAMETER         6.0   WETTED AREA    528.4  163.0   27.0
T/W       1.05   VOLUME         994.7   SPAN            29.1   20.6    6.5
NZI ULT   12.0   WETTED AREA    742.4   L.E. SWEEP      58.0   58.0   48.5
CREW.       1.   FINENESS RATIO   7.9   C/4 SWEEP       50.5   44.3   35.0
PASSENGERS  0.                           ASPECT RATIO     2.1    3.0    1.3
                                         TAPER RATIO      0.1    0.2    0.3
ENGINE                 WEIGHTS           T/C ROOT         0.04   0.04   0.04
                                         T/C TIP          0.04   0.04   0.04
NUMBER      2.                  W    WG   ROOT CHORD      25.0   11.3    8.0
LENGTH    14.2   STRUCT.    5961. 19.4   TIP CHORD        2.5    2.4    2.4
DIAM.      2.9   PROPUL.    6327. 20.6   M.A. CHORD      16.0    7.8    5.7
WEIGHT   3069.1   FIX. EQ.   4708. 15.3   LOC. OF L.E.    17.5   36.2   39.5
TSLS     16100.   FUEL      12230. 39.8
SFCSLS    2.04   PAYLOAD    1533.  5.0

                MISSION SUMMARY

PHASE     MACH     ALT     FUEL     TIME    DIST      L/D  THRUST      SFC      W
TAKEOFF            500.     673.     6.0  3494.9
CLIMB     0.99   44000.    1765.     2.5    18.3      4.1 10255.8      2.2    223.8
CLIMB     1.54   50000.     133.     0.2     3.5      2.6 13205.2      2.1    402.4
CRUISE    1.60   51390.    3517.    12.0   189.1      2.7  9823.5      1.7    408.4
COMBAT    0.90   30000.    1698.     2.9    25.6      5.6 16698.8      2.2    357.0
COMBAT    1.20   30000.    1236.     1.6    18.8      4.0 21636.1      2.1    634.7
CRUISE    0.90   50593.    1146.    23.8   205.0      6.5  3109.0      0.9    134.3
LOITER    0.40       0.    1862.    22.0    97.0      8.0  2604.4      2.6    237.0
LANDING                                   8034.9

BLOCK TIME  =  1.084 HR
BLOCK RANGE =  551.4 NM

                          COMBAT PHASES

MACH   ALT   PSIG  NZS   CLS    CDS   ALS   NZI   PSI   CLI   CDI    ALI   CBE
0.90 30000.  468.  3.3 0.549 0.1106 10.9  7.5 -5282. 1.229 1.1049 40.0 81371.
1.20 30000.  402.  3.9 0.340 0.0848  5.8  8.0 -1645. 0.705 0.2079 12.4 39613.
```

The output of the ACSYNT program is always described by a complete set of data independent of the number of input data. All the physical dimension data, weights, engine size and cycle, wing geometry, and fuel quantities are presented. This does not represent an optimized solution but a point solution that meets mission requirements based on the input data. The optimum solution is obtained by a numerical regression, optimizing the design variables to derive the minimum size vehicle.

ACSYNT OUTPUT VEHICLE



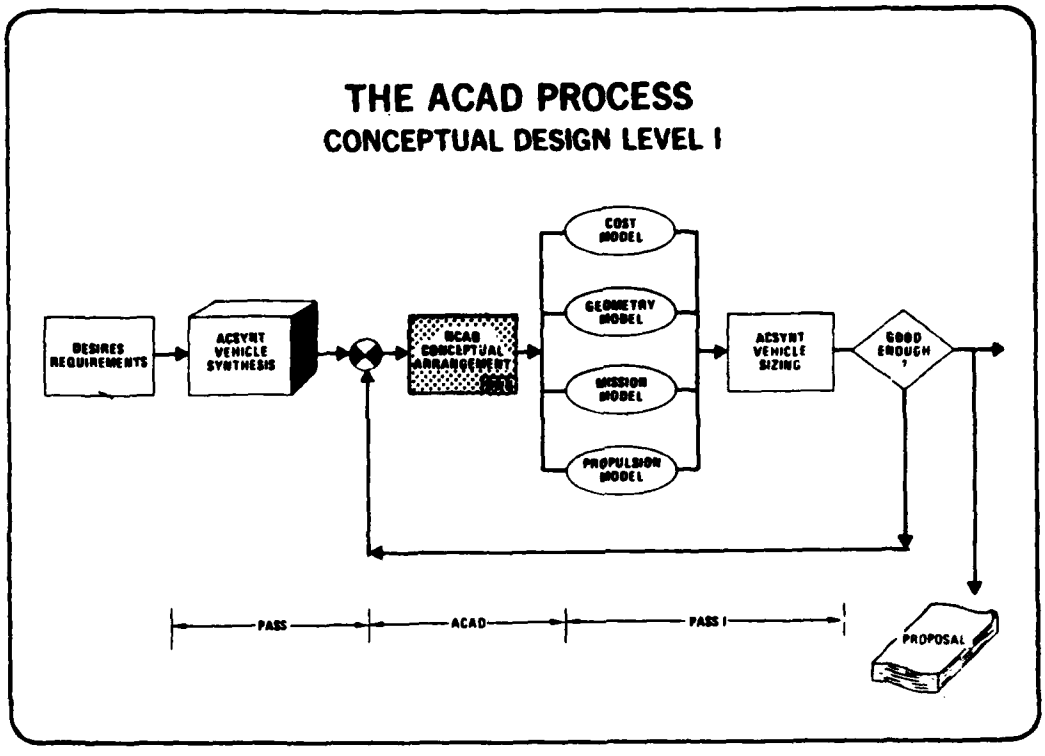
Along with the tabulated output data, ACSYNT also likes to draw a picture of its solution. Being limited to very basic tools, i.e., stars, dots, and X's, it tries its best to construct a two-view drawing. Note, no engine inlets or canopy.



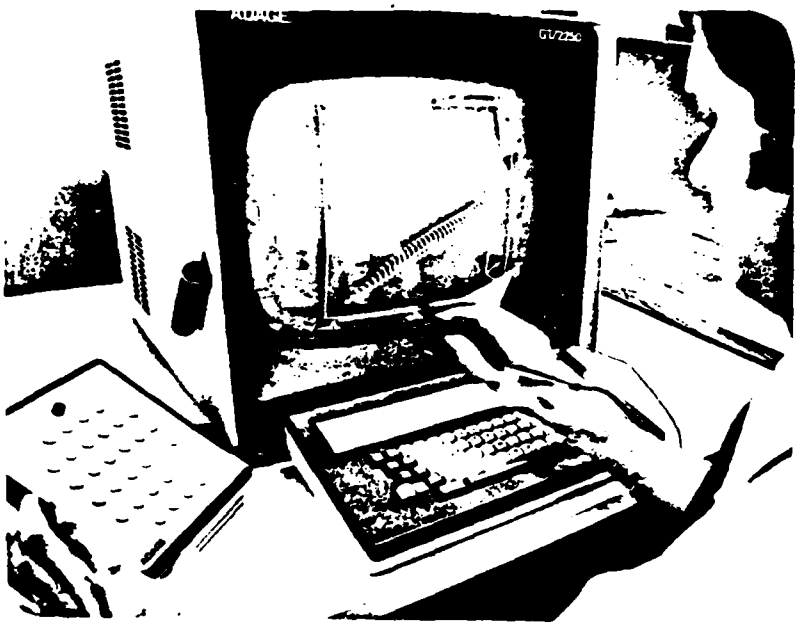
EVOLUTION OF THE
DESIGN PROCESS

Since the very beginning, man has tried to express his dreams in some graphic manner. The earliest man used the crudest of tools for drawing and calculations were limited to counting on his toes. As time passed, the dreams became more sophisticated and the tools necessary to communicate these dreams developed from T squares to drafting machines and computing tools evolved from slide rules to programmable hand-held calculators.

Tomorrow's airplane will be defined with tomorrow's computer-aided drawing and analytical tools. One such hardware/software system, the Advanced Configuration Analysis and Design (ACAD) system, is currently being used at Northrop.



The conceptual arrangement is the designer's chance to stylize the concept and hopefully make it a workable design. The design tool utilized here is the NCAD three dimensional graphics system which creates a three dimensional drawing of the vehicle and defines it with surface patches. The resulting drawing represents a concept which has been packaged and refined to show cockpit, inlets, landing gear, weapons, subsystems, and fuel tankage.

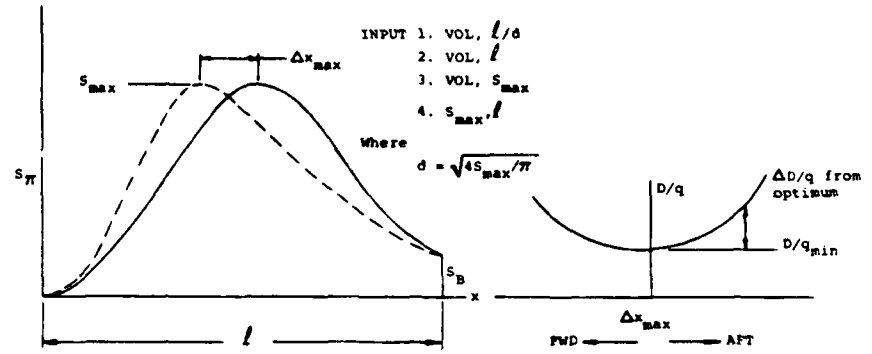


The ACAD system consists of an ADAGE GT/2250 display console or equivalent, with related display control units and long line adapters, a large IBM system 370 computer with its related disk, drum and tape storage systems, a Universal Drafting Machine Orthomat plotter system, and a Versatec or Gould electrostatic plotter system.

The ACAD designer uses the designers' console as an input/output device for graphics operation. Two of these consoles are connected to a display control unit which accepts data and cues the data for transmission to the computer system in another complex.

The console provides high-speed exchange of data and visual display between the computer and the designer. The console displays tables, graphs, charts, drawings, and alphanumeric data on the face of a cathode-ray tube. The function keyboard, alphanumeric keyboard and the light pen supply the means for entry and change of displayed information.

OPTIMUM WAVE DRAG
BODY OF REVOLUTION

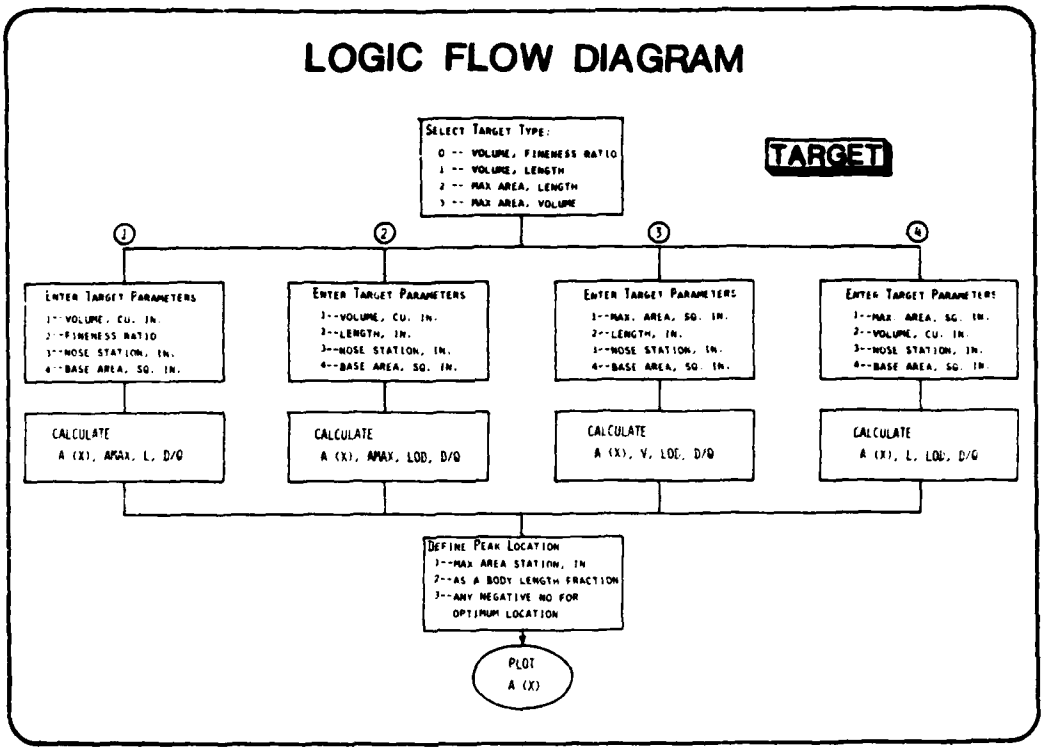


$$D/q(\ell/2)^2_{min} = -\frac{1}{2\pi}\int_{-1}^{1}\int_{-1}^{1} S''(x)S''(\xi)\log_e|x-\xi|dx + \frac{S^1(1)}{\pi}\int_{-1}^{1} S''(x)\log_e(1-x)dx - \frac{1}{2\pi}\left[S^1(1)\right]^2\log_e\frac{\beta}{2}\sqrt{\frac{S(1)}{\pi}}$$

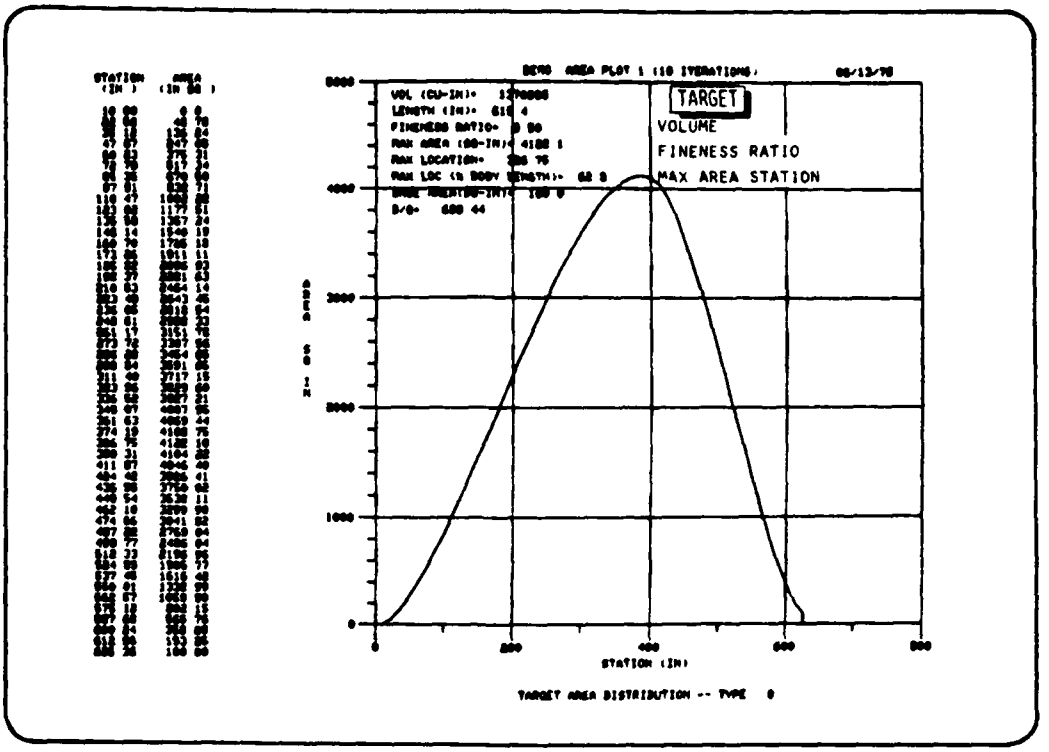
Given a body of revolution in a supersonic flow field, its wave drag is a function of the distribution of the volume in the free stream direction. Using the methods of Adams*, an optimum distribution of volume for minimum wave drag can be calculated. In the equation shown in the figure, the variables of volume, fineness ratio (length divided by diameter), and maximum cross sectional area can be combined with two as dependent variables and the third being the independent variable. It is then possible to calculate an optimum distribution of volume.

However, it not always possible for the designer to place the maximum cross-sectional area of the aircraft at the point for minimum drag. Consequently, it is necessary to assess the drag impact of skewing the distribution for a new peak location and consequently calculating a new target area distribution for this location. When the net volume of the airplane has been determined, the designer uses the Adams method to produce an overall target area distribution as shown above.

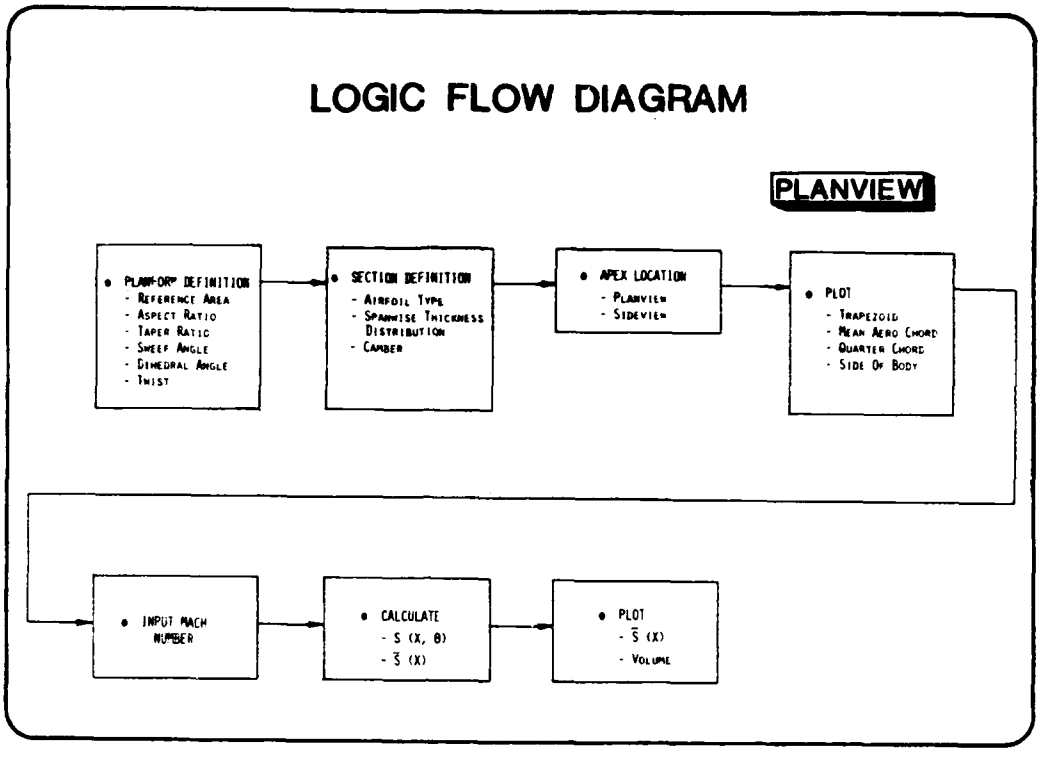
*Adams, Mac C., "Determination of Shapes of Boattail Bodies of Revolution for Minimum Wave Drag, NACA TN 2550, August 21, 1951.



The target program provides the designer with a total aircraft target area distribution from parameters of volume, fineness ratio, overall length, and maximum cross-sectional area. Only two of these parameters are needed to develop an optimum shape with the other two parameters taken as dependent variables. The target types correspond approximately to the Adams target types. After the user selects the target type and enters the two basic parameters, with a further notation of the nose station and base area, the target area distribution may be selected either with the peak located at an optimum location, at a specific location, or as a fraction of the body length. With any of these options, a relative drag value is calculated and included on the face of the plot.

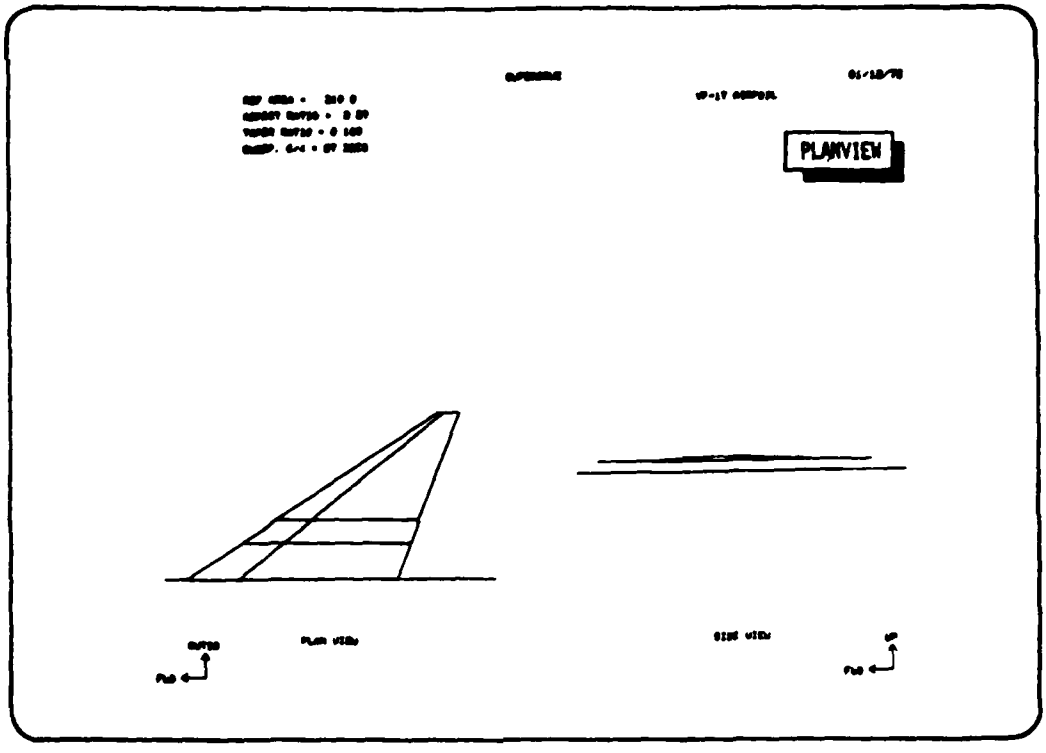


This is a typical output of the target program where volume, fineness ratio, and specific station for the maximum area were utilized as program inputs. The resulting target area distribution has a value of $\frac{D}{q}$ = 699 square inches. For convenience, the data are plotted digitally to the left of the plot.



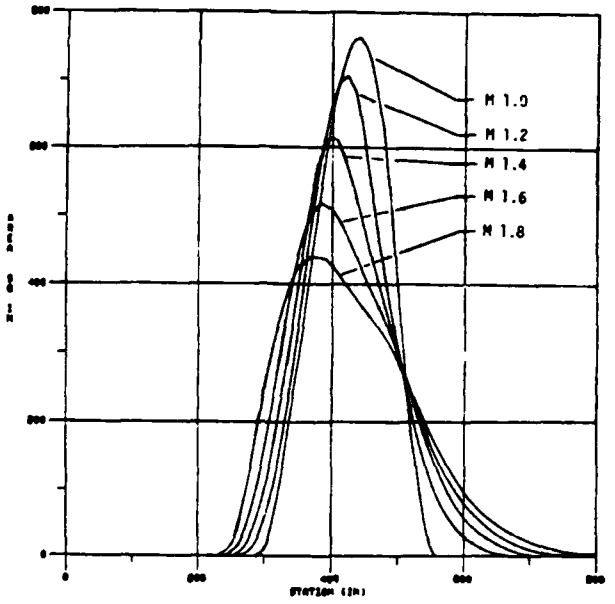
The planview program allows the designer to calculate wing and empennage planview drawings as a simple entity by using standard geometric parameters. Equivalent cross-sectional area distributions are also calculated.

This diagram summarizes the input parameters required for the planview routines to define wing and empennage planforms, develop section definition, and calculate the equivalent area distribution of the exposed surface as a function of the design Mach number.

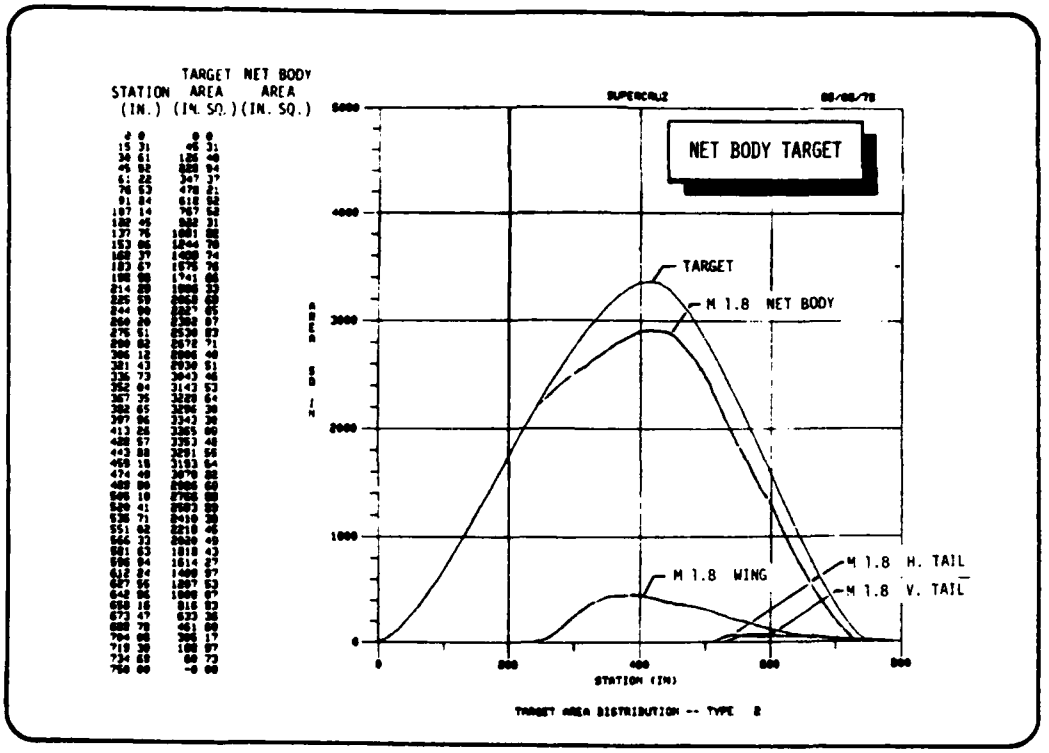


This is a sample printout of the planview program which enables the designer to readily visualize the wing in both plan and sideview. For convenience, the major geometric parameters are summarized automatically on the drawing.

MACH EFFECTS ON WING AREA DISTRIBUTION



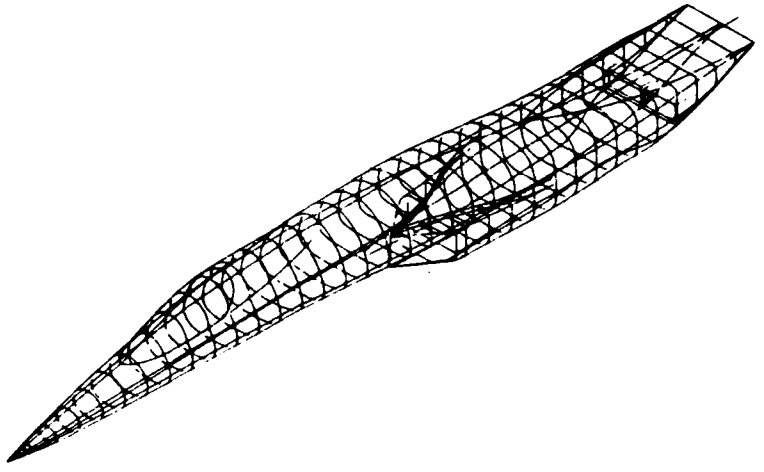
The angle of the cutting plane is equal to Sin^{-1} (1/M). Thus, with increasing Mach number the cutting planes are passed through the wing and empennage at increasing angles. The effect of this increase in Mach number is to "smear" the area distribution as shown in the figure above. Note that the volume is constant under all of these curves. Since the target body area distribution will be greatly affected by the particular wing area distribution, which is subtracted, it is important for the designer to estalish at the outset which design Mach number will be used to optimize the body.



The net body target program is a simple summation program which subtracts the wing and empennage equivalent area distributions from the overall target to produce a net body target.

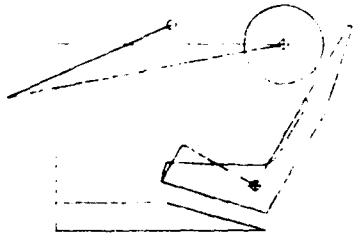
The resulting net body target is shown here for a design Mach number of 1.8. This module is in the development stage and when completed will present the designer with the display shown plus the rapid capability to shift wings and empennage fore and aft, and will also present the body equivalent diameter.

BODY DEVELOPMENT

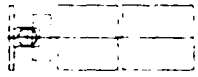


The following charts will sequentially depict the development of the body shown in this figure. The drawing of the control lines, construction of the sections, and calculation of the cross-sectional area distribution is presented.

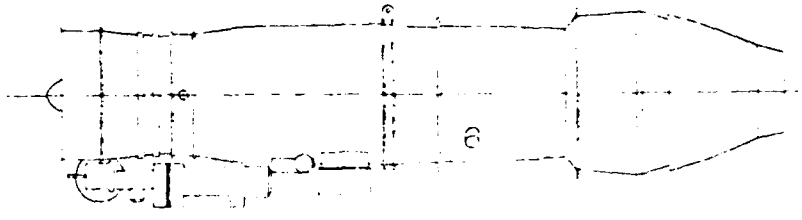
STANDARD LIBRARY EXAMPLES



30° SEAT



RADAR

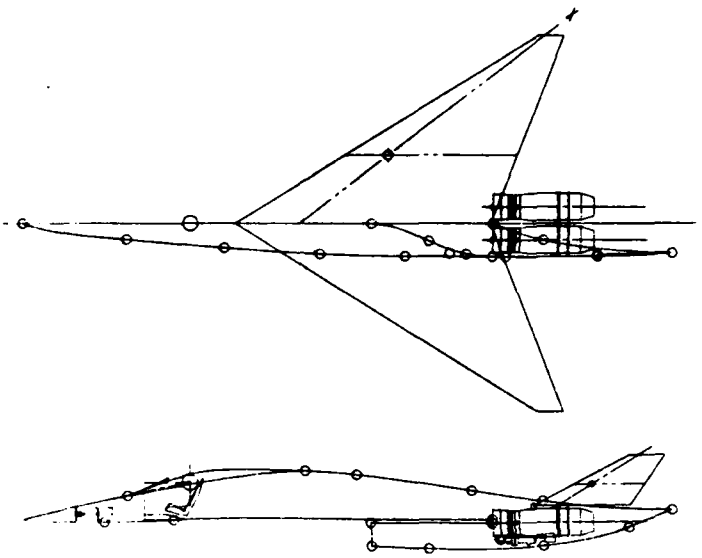


ENGINE

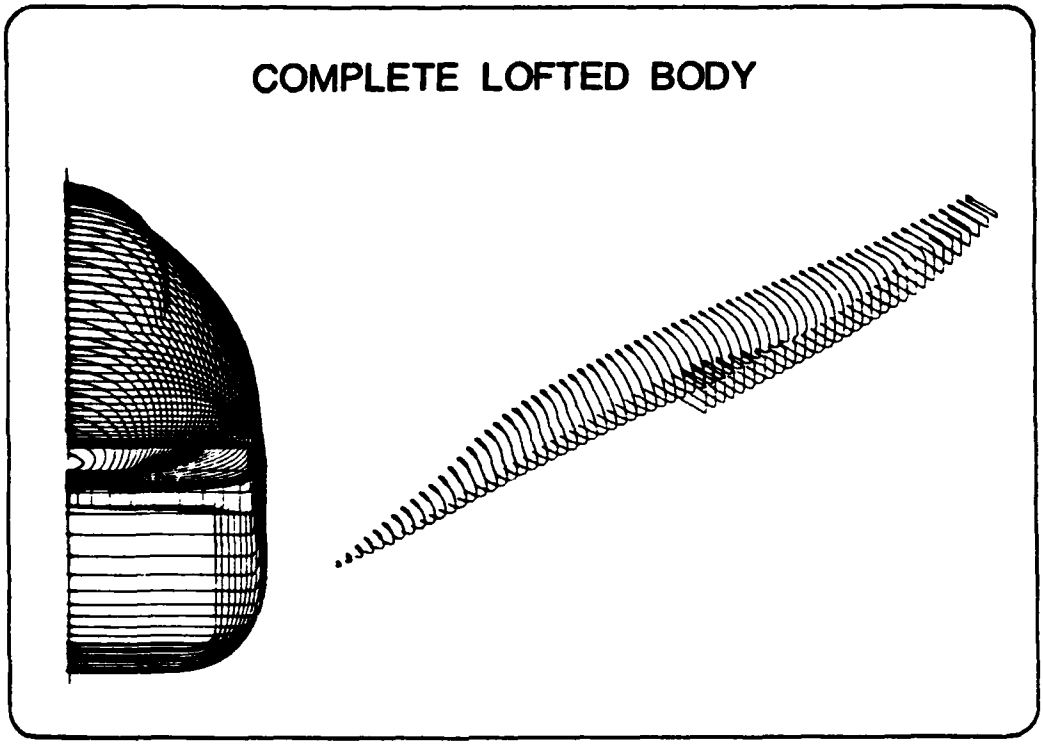
Within the user's CADAM drawing files, or stored within libraries, are several baseline components such as radars, crew stations, and engines. The components shown in this picture do not represent actual hardware options, but rather generic concepts depicting the scope of detail necessary for the designer to begin the process. The crew station above shows the essential elements of seat back angle, helmet clearance, and eye and seat reference points.

It should be noted that CADAM enables the designer to scale independently in both X and Y; for example, engines scale differently in diameter and length as a function of thrust. Using the CADAM capability, an engine can be rapidly derived through this scaling option.

CONTROL LINES DEVELOPMENT



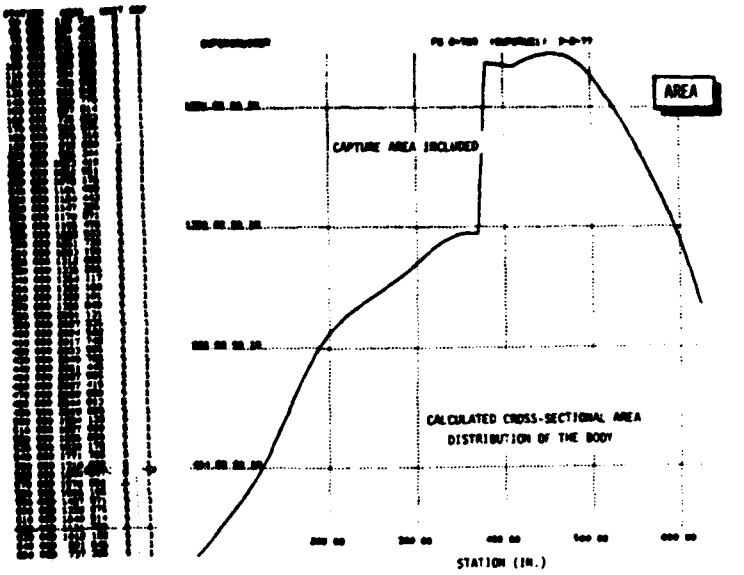
Once the overall configuration length has been determined, the system modules may be "hung" on the screen in any location and orientation selected by the designer within these limits. He then assures adequate clearance as shown by the data points circled for reference on this drawing. Once satisfied with this placement, the designer then uses the CADAM functions of splines, conics, lines, and circles to draw the control lines. These control lines can be readily displayed, and changed, with the stroke of a light pen. This procedure of defining the external control lines of the airplane continues until adequate definition exists for the construction of three-dimensional shapes.



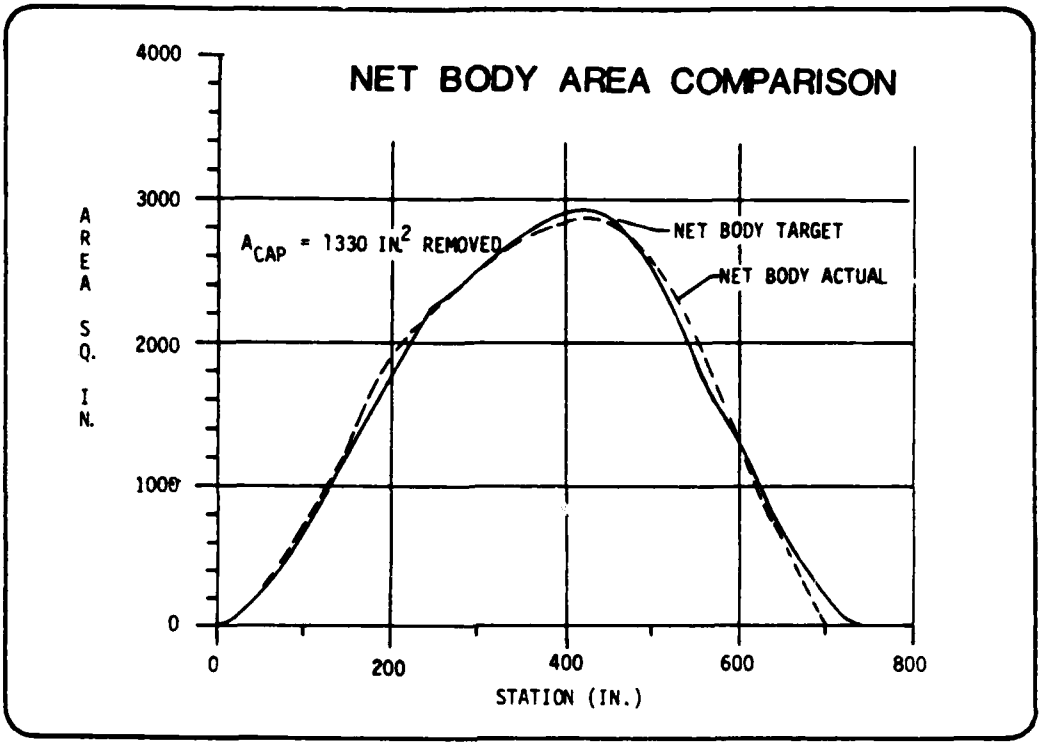
The figure above demonstrates the desirability of large main frame models for configuration control. In this view, seventy complex sections were generated on the screen without filling the model or the buffer. The ability to use this dense spacing of sections for control of asthetics is well illustrated.

Display flexibility permits viewing the sections on one or both sides, either head-on or in isometric view.

ACTUAL NET BODY AREA DISTRIBUTION

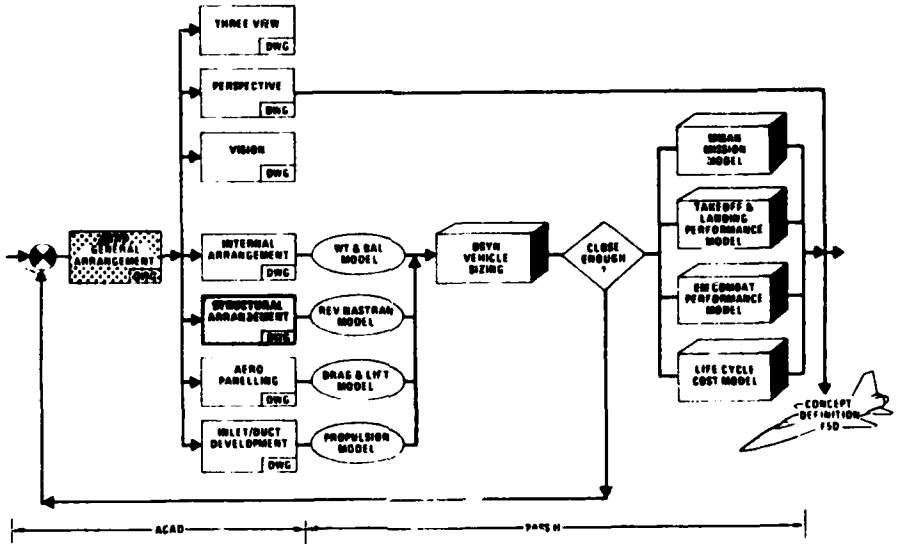


When the designer is satisfied that the body lines are properly faired and that adequate clearance is available for all of the major subsystems, he may then enter the AREA subroutine and calculate the actual cross-sectional area distribution as a function of body station. This example shows both the plotted area distribution and the digital values displayed simultaneously on the screen. The discontinuity between stations 370 and 380 occurs at the inlet and represents the inlet capture area.



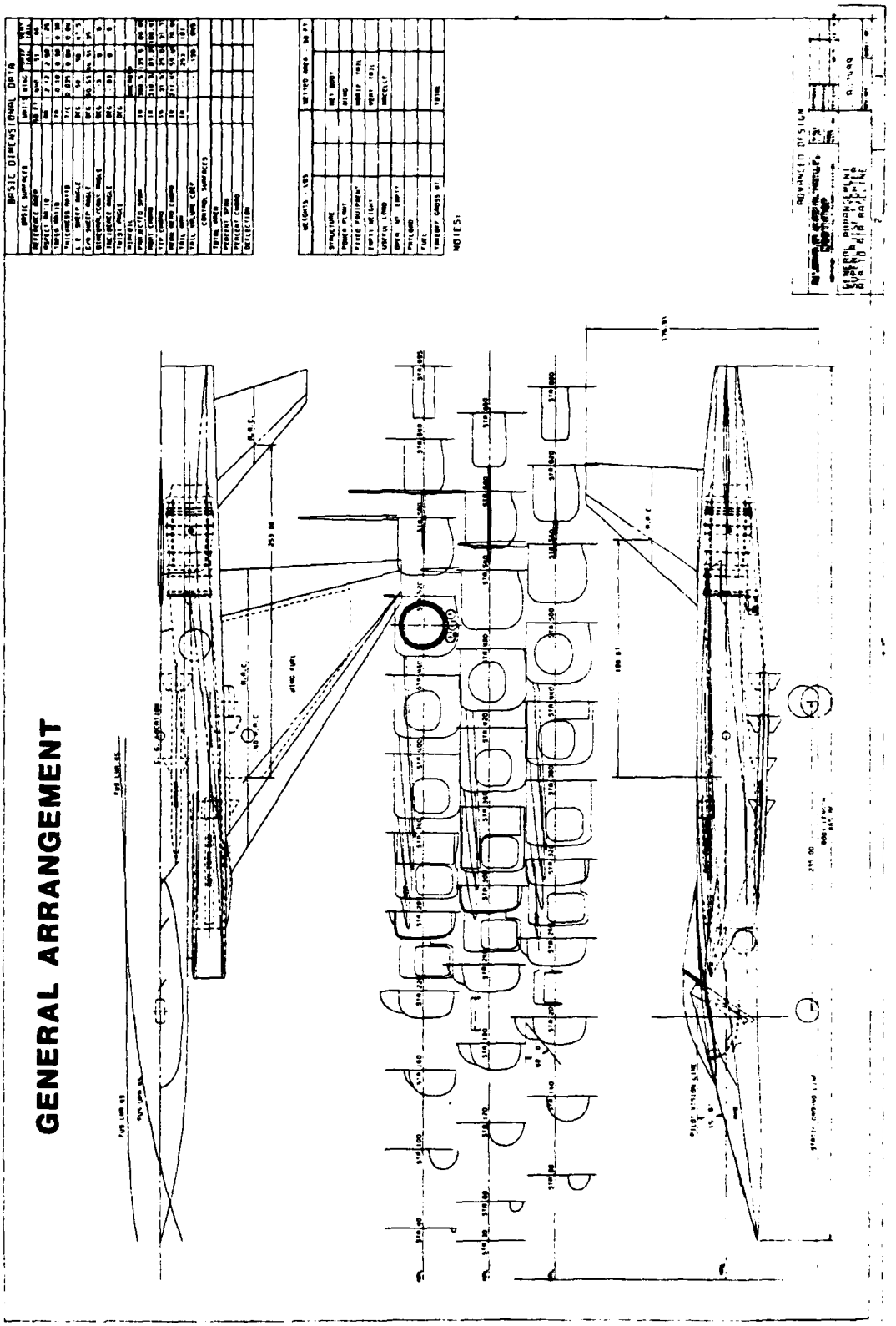
With the engine inlet capture area removed, the body actual area distribution can then be compared with the net body target area distribution shown on page 28. At this point, the designer has the option of revising the control lines and/or the target area distribution as appropriate.

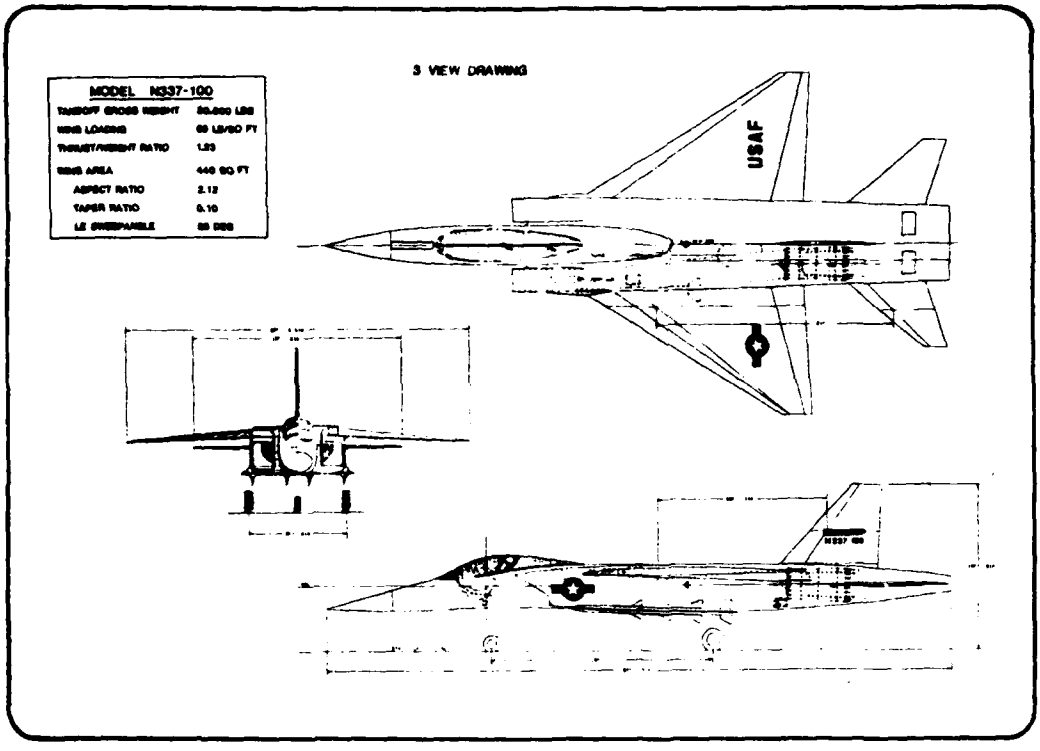
THE ACAD PROCESS
PRELIMINARY DESIGN LEVEL II & III



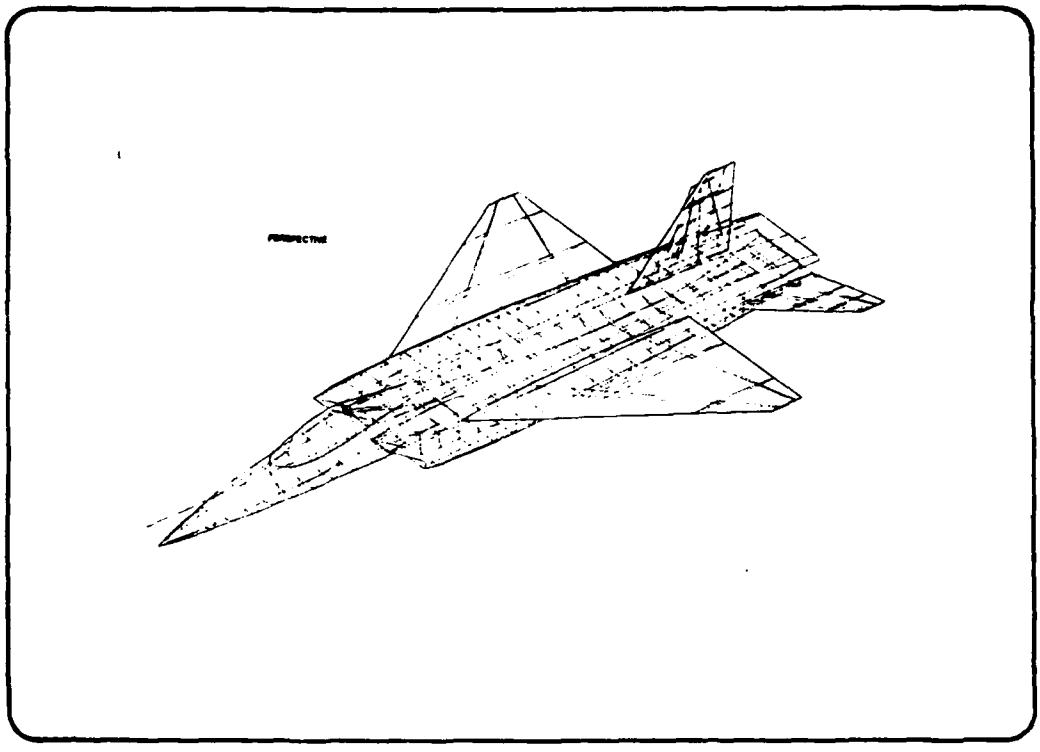
The General Arrangement Drawing becomes the principal vehicle definition and the collector of all design inputs in the preliminary design phase. This level of the design process represents a more detailed and complete effort as is reflected by the number of supporting drawings. These drawings must be of sufficient detail to assure that all systems fit, there is structural integrity, and that the external lines are smooth and continuous.

GENERAL ARRANGEMENT



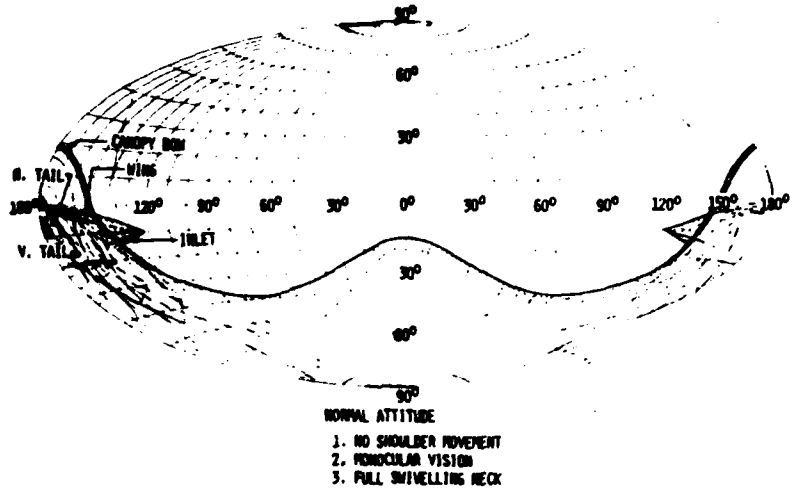


An example of a report-quality 3-view drawing produced from the ACAD general arrangement drawing. This drawing can be produced and revised rapidly utilizing ACAD.

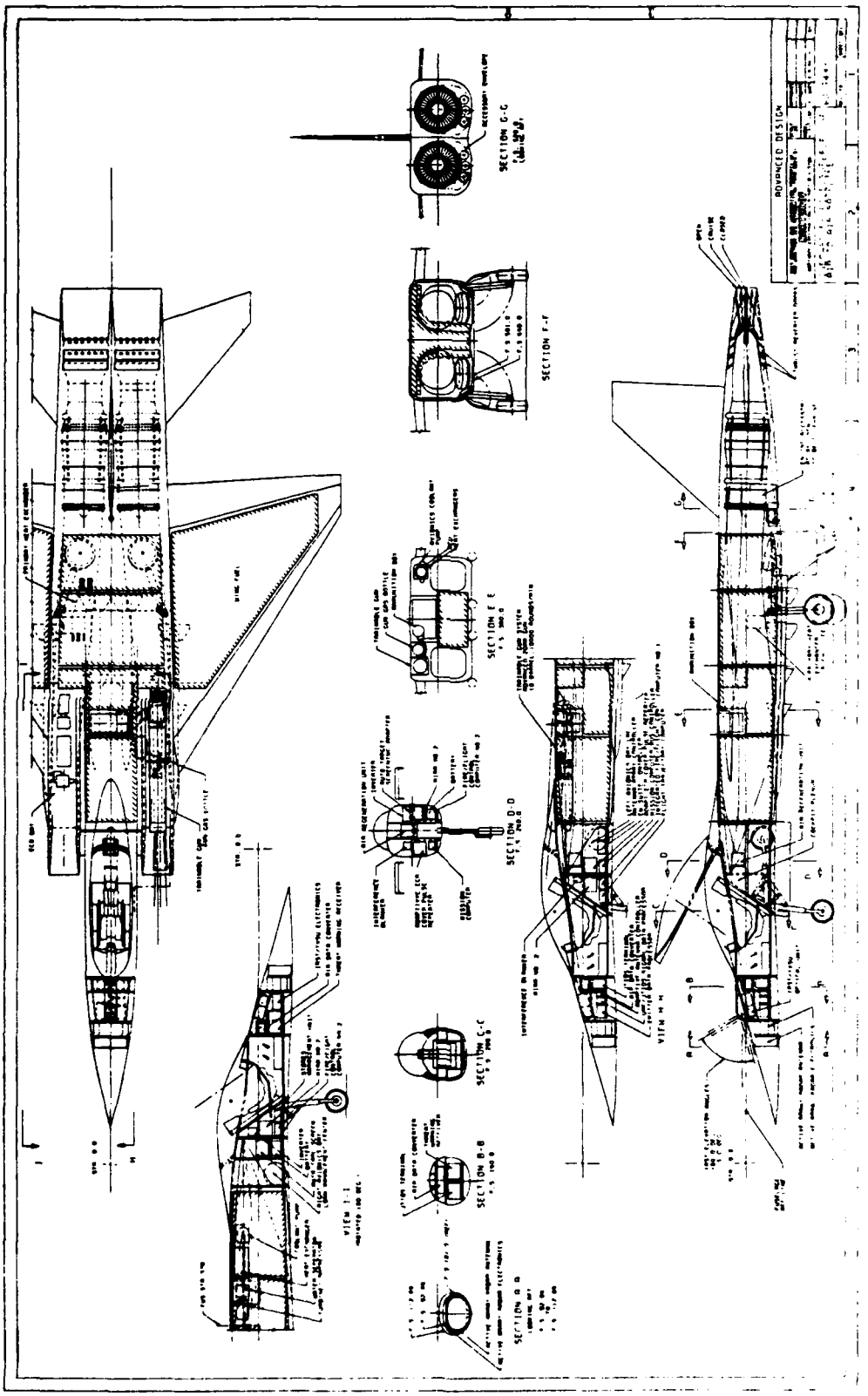


Perspective drawings can also be produced for visualization and artist renderings. Any angle of rotation or eye location can be used.

AITOFF'S EQUAL AREA

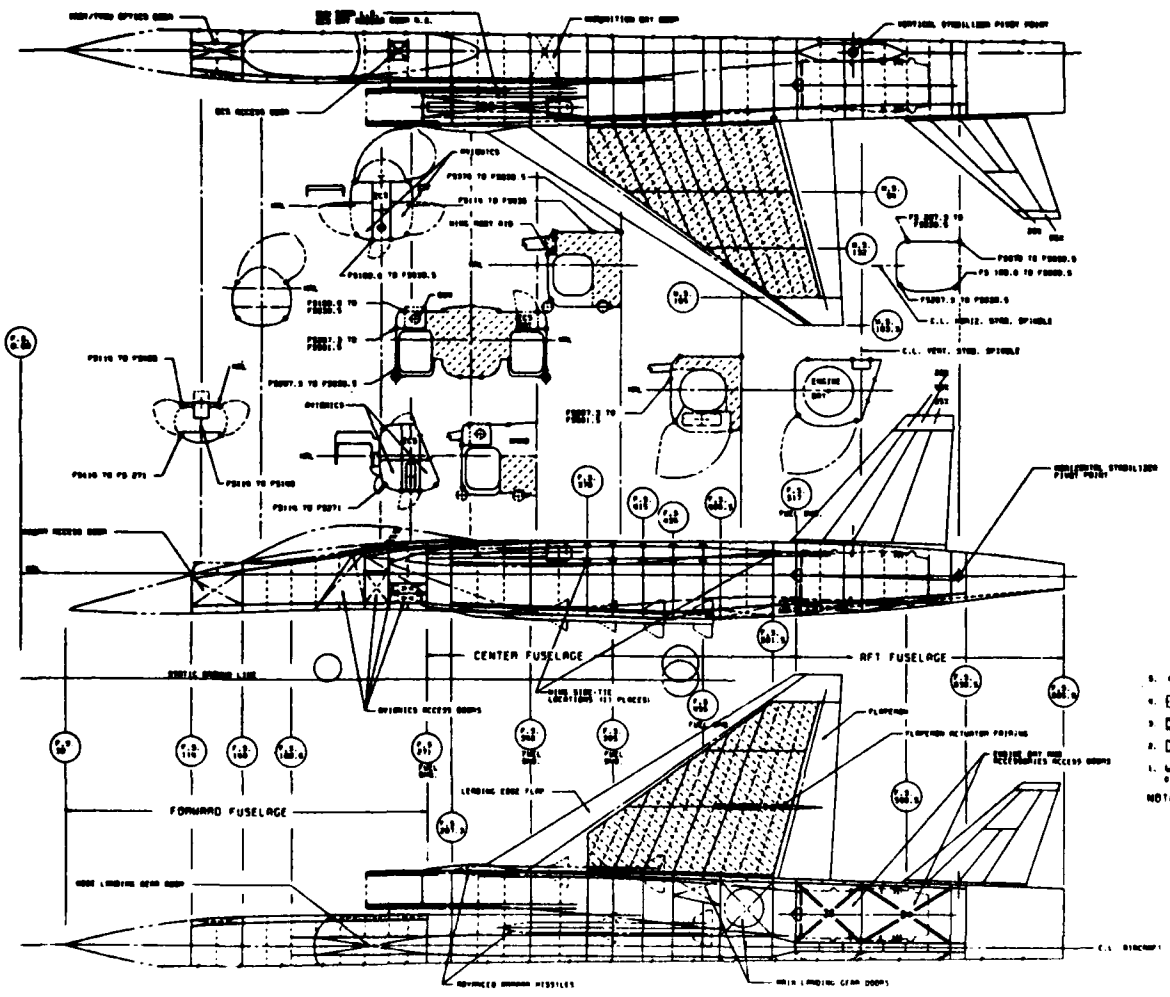


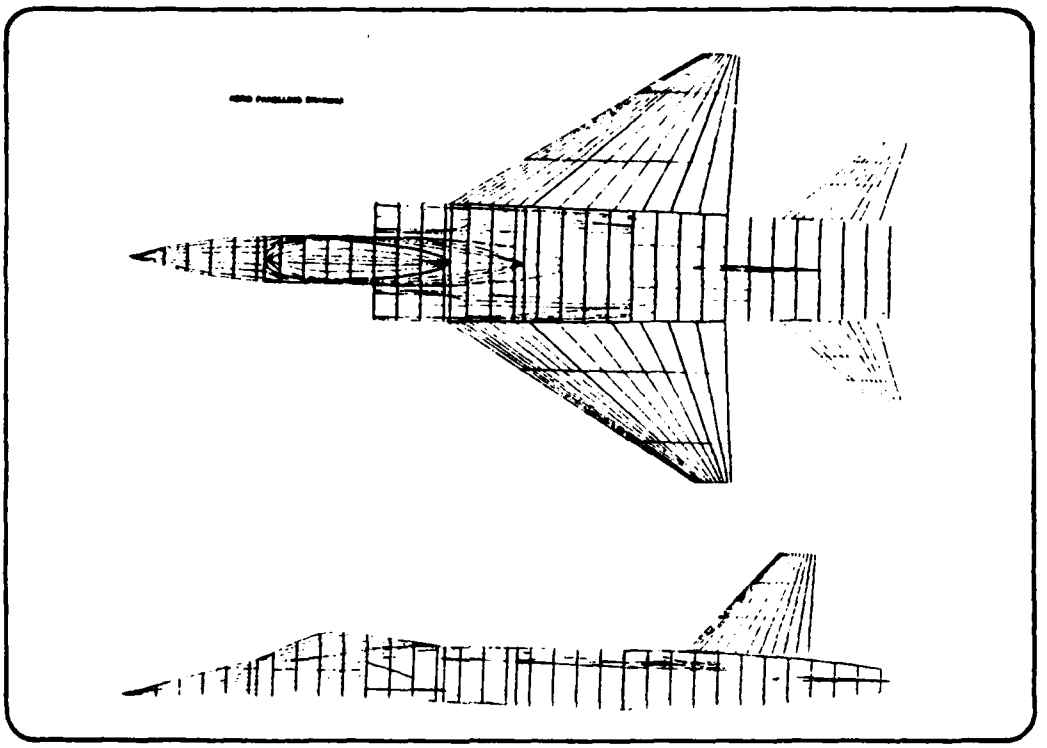
Aitoff's vision plots are a standard representation to show the pilot's vision from his position in the cockpit. This type of plot used to take days to generate by hand, but now with computer graphics can be accomplished within minutes.



INBOARD PROFILE

STRUCTURAL ARRANGEMENT





Aero paneling can be accomplished utilizing the geometry definition data set and the ability of CADAM to divide sections into equal segments. This data set can be easily transferred into 3-D surface patch data for utilization in automatic paneling programs.

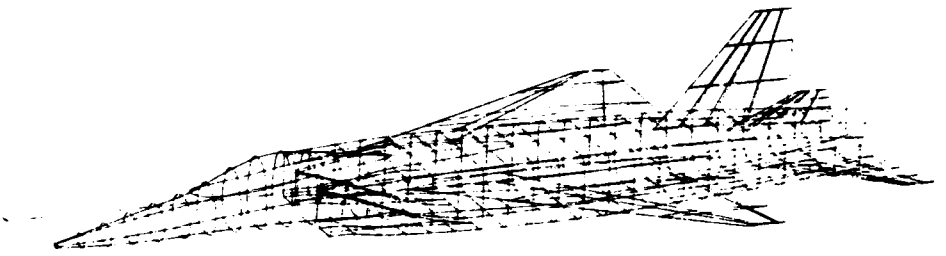
APPLICATIONS OF COMPUTER GRAPHICS TO SURVIVABILITY MODELS

Computer graphics have opened up a new dimension in survivability assessment. Aircraft designed using computer graphics have a display capability that was not previously possible and possesses a computer data set that permits rapid analysis. Computer graphics allows the designer to inspect his concept and, if necessary, make fast and accurate iterations.

INPUTS TO SIGNATURE MODELS

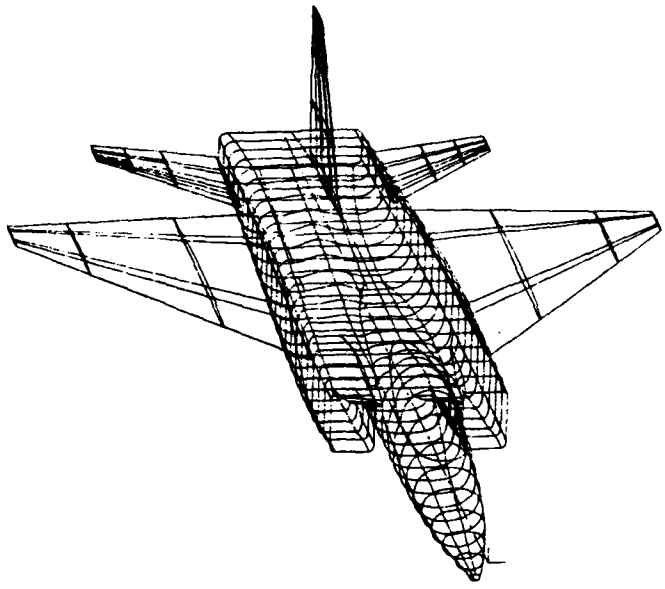
One area of survivability analysis is the ability to elude detection. There are three principal areas in the signature detection spectrum, i.e., optical, infrared, and radar.

OPTICAL



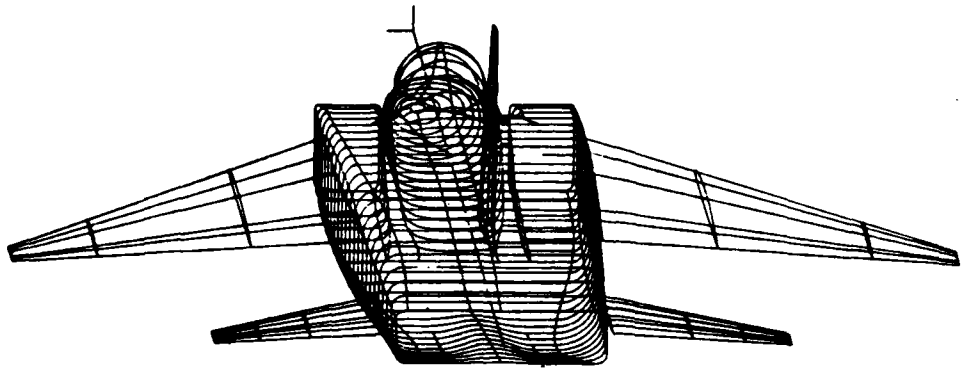
Using a computer graphics three-dimensional data set, an optical model can be generated to show the visibility of the vehicle at any altitude and/or illumination condition. This graphic system was developed by NASA and is referred to as the DICOMED system.

INFRARED



The geometric aspect of infrared modeling can easily be accomplished by graphically examining hot sections of the engine installation and determining at what aspect these areas are visible. This process is presently done manually on the display tube but could be automated to plot the temperature gradients with aspect angle.

RADAR



The electromagnetic evaluation is a combination of both the optical and the infrared technique. The NASA DICOMED system can be used to give reflectivity of edges and surfaces, while the engine face can be examined geometrically to determine the aspects it is visible.

INPUTS TO VULNERABILITY MODELS

Computer generated vulnerability drawings offer great versatility in detail of subsystem descriptions, structural elements, fragment impact points and fragment aspect angles. Almost free are the available geometric details of fuel system tank locations, fuel level variation and explosion protection system effectiveness. This all starts with the basic drawing (shown) and the subsequent inboard profile of subsystem elements. In the conceptual design phase, aerodynamic lines, structures concepts and initial subsystem arrangements provide the major input for preliminary analysis of vulnerable areas.

DAMAGE TOLERANT SYSTEMS

A - ARMOR CRITICAL COMPONENTS

B - BURY VULNERABLE COMPONENTS

C - CONCENTRATE FOR ARMOR

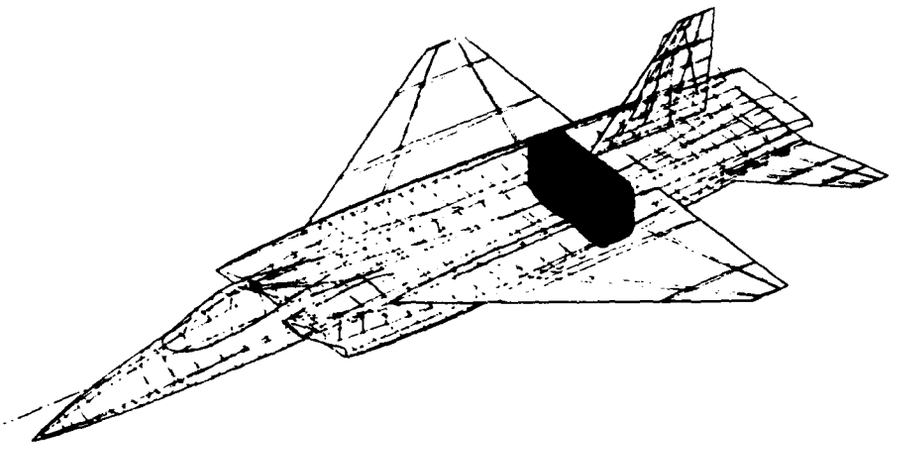
D - DISPERSE REDUNDANT SYSTEMS

E - END FUEL FIRES

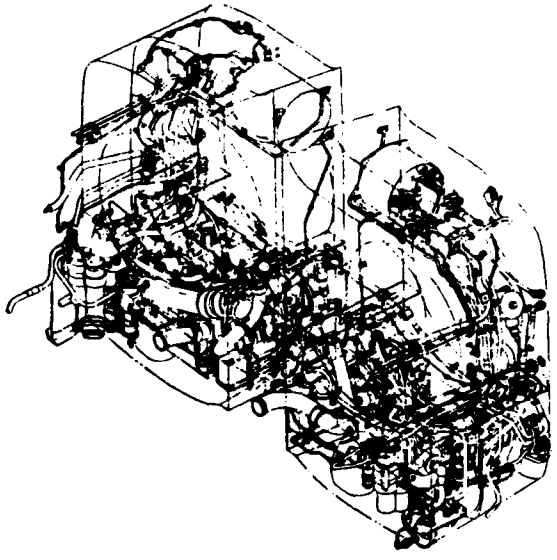
Everything must be kept simple in conceptual design, even vulnerability guidelines. The A B C's of vulnerability, created in the 60's, have served as design guides to the airplane configurator.

- Armor, while listed first, is usually the last resort. Except for pilot protection, armor is usually not included during conceptual design.
- Bury critical elements which would yield a K or A kill. During conceptual design the critical element list includes, ammunition drum, engines, flight control computer, power distribution panel, emergency power generator.
- Concentrate critical elements when armoring is necessary. This is usually done during the second iteration following preliminary analysis for vulnerable areas.
- Disperse redundant elements. A standard approach that produces the maximum separation possible between vulnerable components.
- End fuel fires - a reminder to avoid fires by including inert gas, foam of other explosion protection and fuel tank arrangements that do not leak on the hot sections.

DISPERSE REDUNDANT SYSTEMS



Dispersal of redundant components has to be achieved through configuration arrangement. Dispersal of redundant subsystems may require entire sections of internal bays. Major equipment, structural arrangement and accessibility will produce constraints on dispersal. Such limitations result in the "dispersed" zone shown here and discussed on the following page.

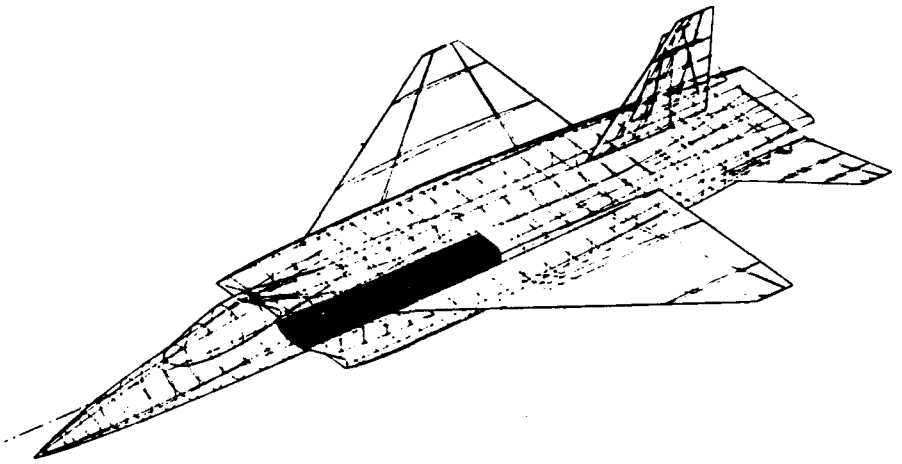


DISPERSE REDUNDANT SYSTEMS

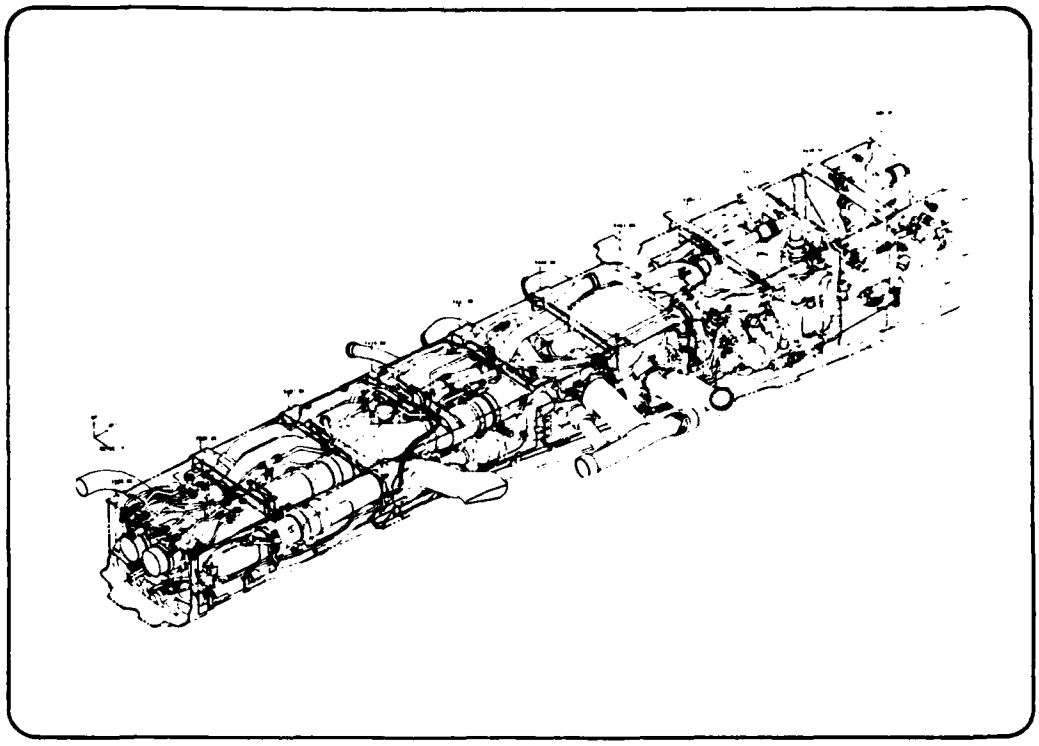
When design development progresses, the detail of subsystem vulnerability gets compromised by maintainability and accessibility considerations. The conceptual designer carries his integration skills forward in development to maintain the discipline in subsystem installations. Detail vulnerability studies are aided by evolving computer generated layouts where the initial stored data is continually updated and expanded to produce, in the end, total detail of all subsystem installations.

This installation of a dual hydraulic system illustrates one end product of dispersed redundant systems.

BURY VULNERABLE COMPONENTS



A typical location for buried subsystems is shown. Protection of this zone is provided by engine inlet structure, forebody structure and components and external stores hardpoints. The following page discusses this in more detail.



ECS SYSTEM

The vulnerable components of concern here are actually above the Environmental Control System shown. Critical avionics and ammo drum are buried above the ECS, behind the pilot and ahead of integral body fuel tanks, thus minimizing armor requirements in the forebody.

Producing total subsystem details, such as shown, produce early results for vulnerable area studies. Computer generated drawings in three dimensions are the key to rapid analysis.

SUMMARY

INTERACTIVE COMPUTER GRAPHICS

WILL :

- INCREASE ACCURACY AND DEPTH OF CONCEPTUAL DESIGN,
- PROVIDE A COMMON DATA BASE FOR DESIGN AND ANALYSIS,
- REDUCE THE TEDIUM OF MANUAL CONSTRUCTIONS, DIGITIZING AND MEASURING.

WILL NOT :

- REDUCE THE TIME FOR CONCEPTUAL DESIGN,
- COME ABOUT WITHOUT A DEDICATED EFFORT,
- BE UNIVERSALLY ACCEPTED BY ALL DESIGNERS,
- REPLACE THINKING.

The impact that interactive computer graphics has had on the design process can be summarized as having increased accuracy and depth of aircraft designs in both the conceptual and preliminary design phases. While the initial time to design an aircraft concept has not shown any significant benefit, the quality of the product has. The reason for this phenomenon has been given as: if a designer is given a specific period to design something, he will take exactly that amount of time. The computer graphics tool speeds up the drawing process, freeing the designer to think of improvements and refinements.

A secondary benefit of aircraft designed using computer graphics is that it provides a common data base for the analyst as well as the designer. This data base reduces the time and tedium of manual digitizing and measuring, thus, providing more time to analyze data and iterate the design.

Above all, we must remember that the computer does not replace thinking.

COMPUTER-AIDED ENGINEERING APPLICATIONS AND INTEGRATION WITH S/V

R.J. Ridgeway and J.G. Avery
Boeing Military Airplane Co.
Advanced Airplane Branch
Seattle, Washington

R.J. RIDGEWAY
BOEING MILITARY AIRPLANE CO.

J.G. AVERY
BOEING MILITARY AIRPLANE CO.

COMPUTER-AIDED ENGINEERING APPLICATIONS AND INTEGRATION WITH S/V

R.J. Ridgeway and J.G. Avery
Boeing Military Airplane Co.
Advanced Airplane Branch
Seattle, Washington

Survivability analysts have always made good use of digital computers. Additionally, one of our primary goals has been to integrate survivability design technology into the design process at the very earliest opportunity. Computer-aided design (CAD) is well-suited to the skills and goals of the survivability community.

Largely as a result of the ATS Study, there has been an increasing interaction between design and effectiveness analysis. Design decisions and technology development are influenced to a major degree by the results of system analyses, which express merit in terms of targets killed per dollar, as an example. As these decisions are made during conceptual design, it is essential that survivability parameters are computed with the same level of accuracy as other design parameters. Full implementation of survivability analysis into CAD will assure that this capability is achieved.

The remaining viewgraphs summarize the CAD implementation approach being implemented by the Advanced Airplane Branch of BMAC and indicate certain capabilities that we feel are desirable for the survivability integration.

-COMPUTER AIDED ENGINEERING-

APPLICATIONS & INTEGRATION WITH S/V

PART 1 -R.J.RIDGEWAY
PART 2 -J.G.AVERY

BOEING MILITARY AIRPLANE CO.
ADVANCED AIRPLANE BRANCH
SEATTLE WASH.

JTCG/AS MEETING
" A WORKSHOP IN SURVIVABILITY & COMPUTER AIDED DESIGN "
FT.WORTH,TEXAS
6-9 APRIL 1981

BOEING

WHERE DOES COMPUTER-AIDED DESIGN APPLY?

	DESIGN	ANALYSIS	MANUFACTURING	ACCURACY
CONCEPTUAL DESIGN (20+ CONFIGURATIONS)	CONFIGURATION LAY-OUT	FUNDAMENTALS		LOW
PRELIMINARY DESIGN I (2-3 CONCEPTS)	PRELIM. INBOARD PROFILES	HIGHER LEVEL PROGRAM ANALYSIS	MODELS & MANUFACTURING CONCEPTS	HIGHER
PRELIMINARY DESIGN II (1 CONFIGURATION)	DETAIL LAY-OUT	HIGHEST LEVEL ANALYSIS	MOCK-UP TOOLING	HIGHEST
DETAIL DESIGN	✓	✓		AS REQUIRED
MANUFACTURING	TOOL DESIGN	OPERATIONS & MATERIAL FLOW	MASTER DIMENSION DATA AND N/C TAPE CAPABILITY	AS REQUIRED

CAD

CAM

BOEING
DATA GRAPHICS APPLICATIONS

COMPUTER-AIDED CONCEPTUAL/PRELIM. DESIGN

WHAT CAPABILITIES ARE NEEDED ?

GEOMETRY

- CREATION
- DISPLAY
- ANALYSIS
- REPRODUCTION
- MANIPULATION & MODIFICATION

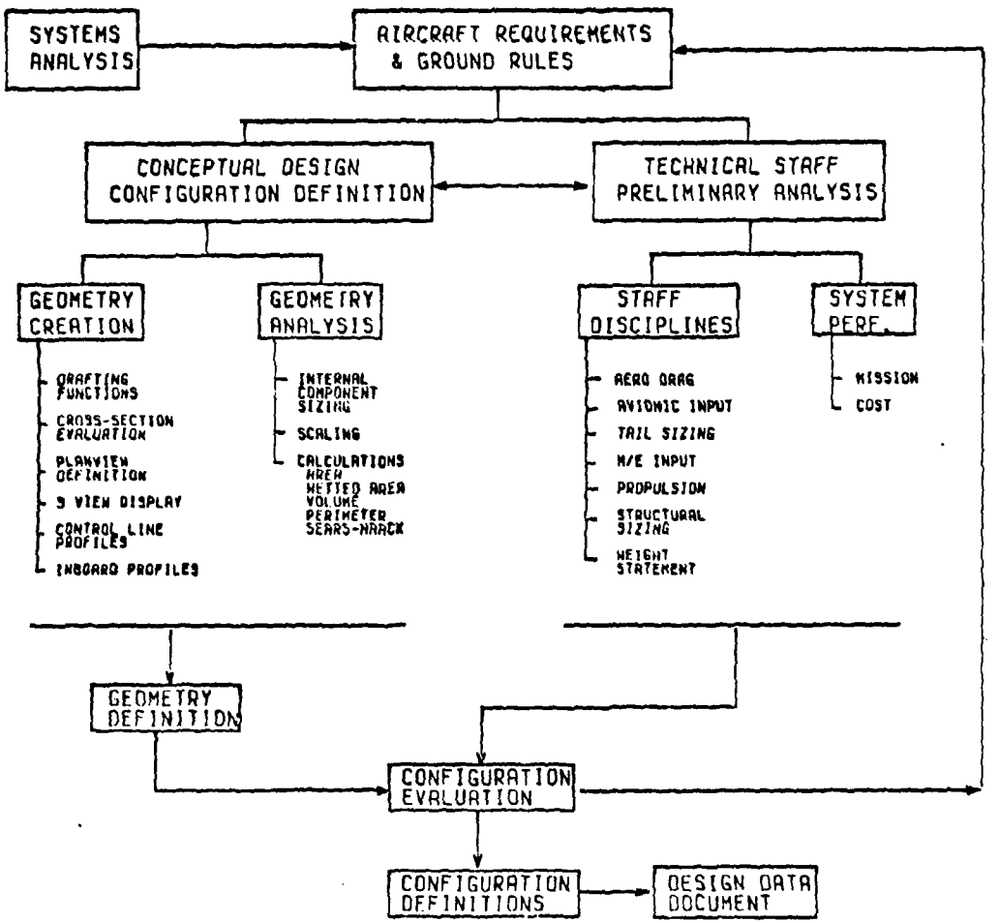
ANALYSIS

- TECHNOLOGY DISCIPLINES
- COSTS

BOEING

DATA GRAPHICS APPLICATIONS

CONCEPTUAL DESIGN FLOW



FLOWMAS.CHT
FG.
1d/3/79

BOEING
DATA GRAPHICS APPLICATIONS

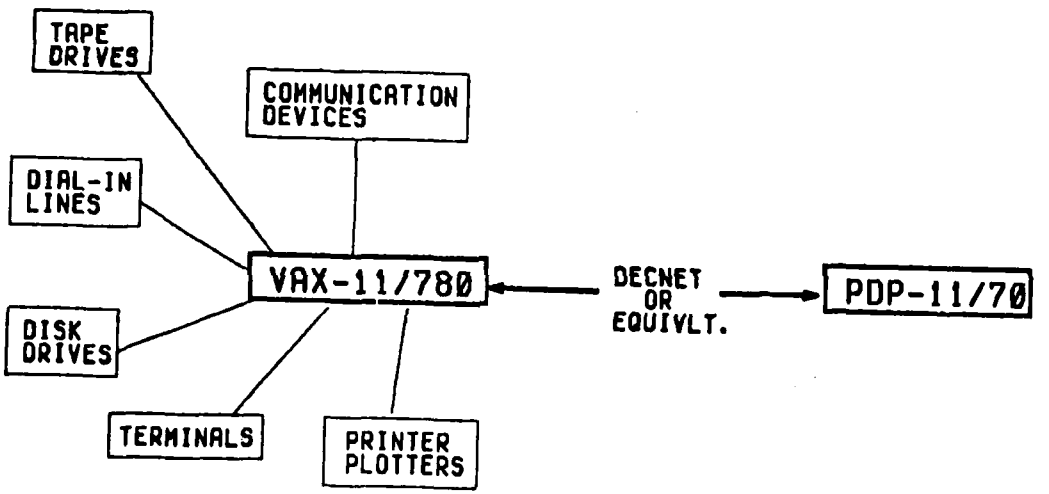
WHAT COMPUTERS & PERIPHERALS SATISFY CONCEPTUAL CAD NEED ?

- MAINFRAME OR MINI ?
  - SELECTION CRITERIA
    - COST
    - CAPABILITY
    - GROWTH
    - VENDOR SUPPORT
  - SELECT MINI
    - VARIAN
    - SEL
    - HARRIS
    - DIGITAL EQUIPMENT
    - PRIME
    - UNIVAC
    - IBM
    - OTHERS

BOEING

DATA GRAPHICS APPLICATIONS

HOW SHOULD MINI.S BE STRUCTURED ?



CONCEPTUAL CAD PROCESSING

CAD GRAPHICS

FDL17.CHT
10/3/79

BOEING

DATA GRAPHICS APPLICATIONS

PERIPHERAL EQUIPMENT

GEOMETRY CREATION & DISPLAY -- GRAPHICS TERMINALS

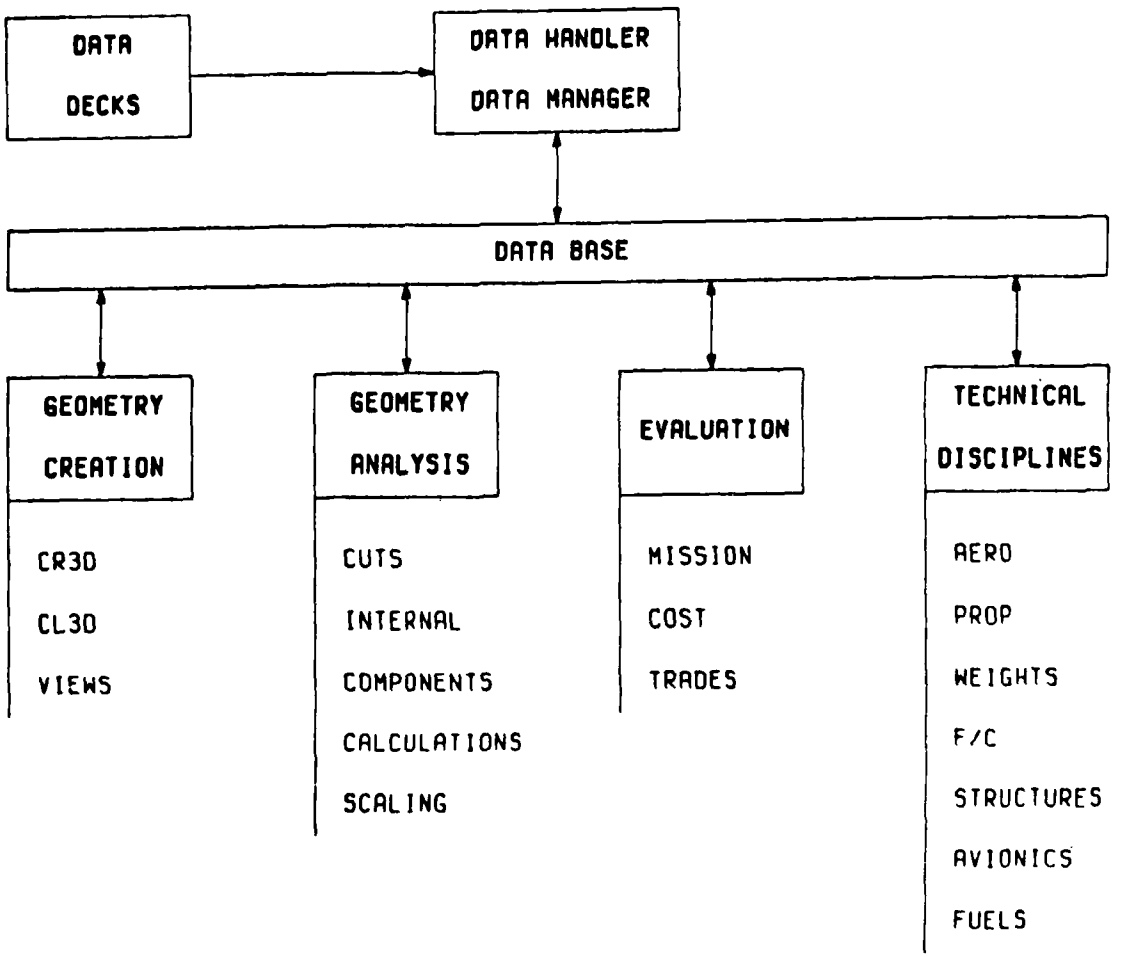
- ADAGE
- VECTOR GENERAL
- TEKTRONIX
- E & S

REPRODUCTION

- GOULD
- GERBER
- CALCOMP
- TEKTRONIX
- VERSATEC

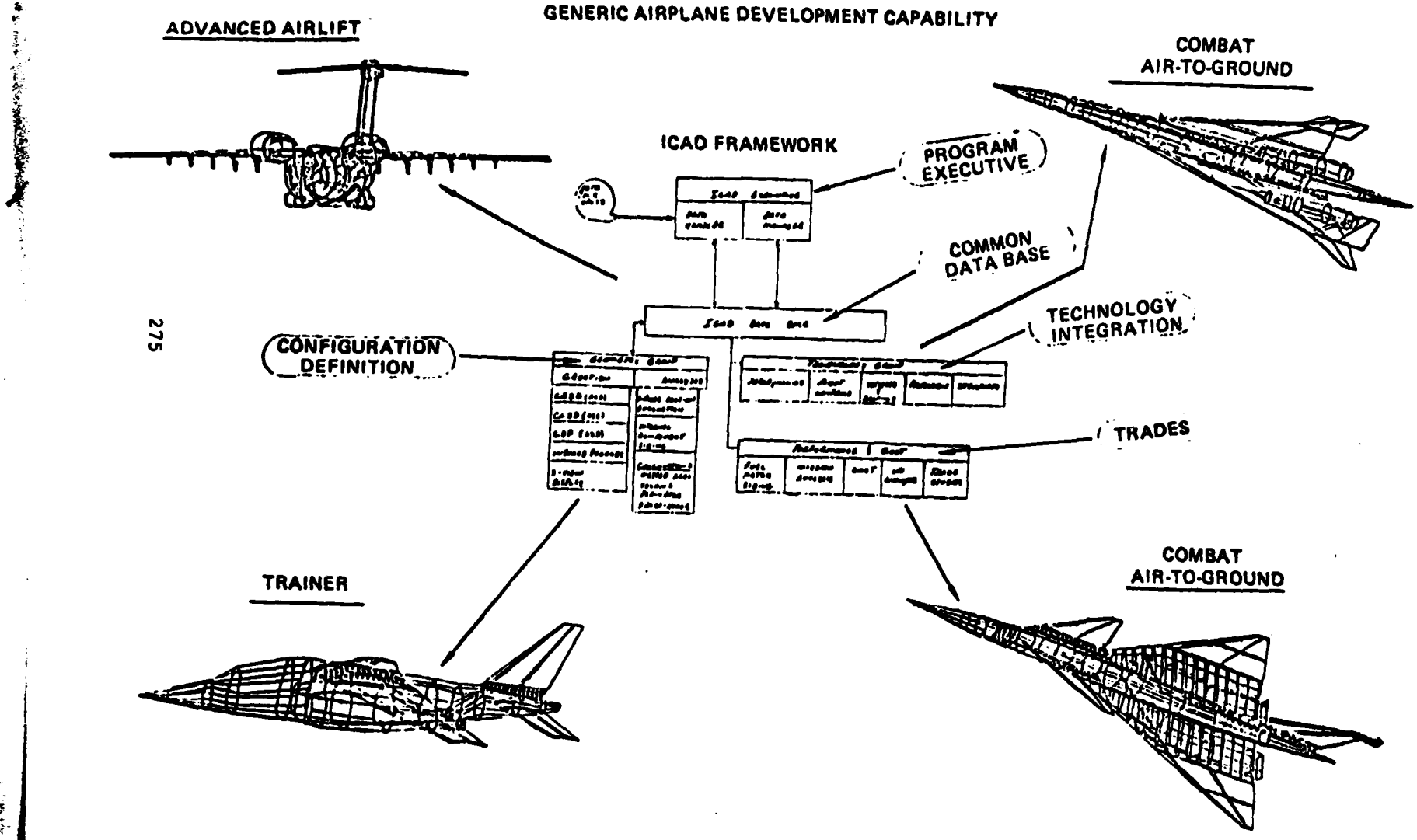
EXPECTED PROGRAM STRUCTURE

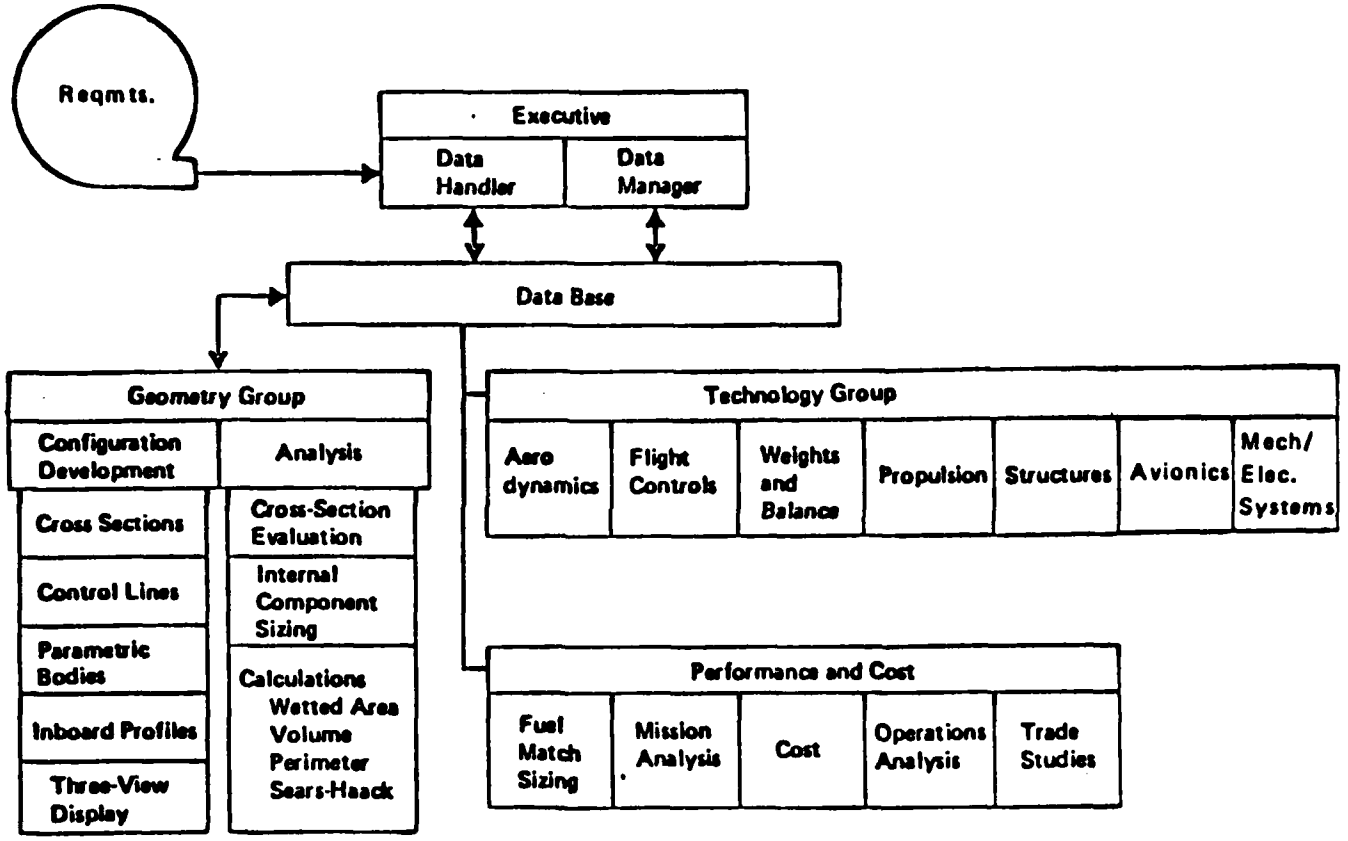
(ONE APPROACH)



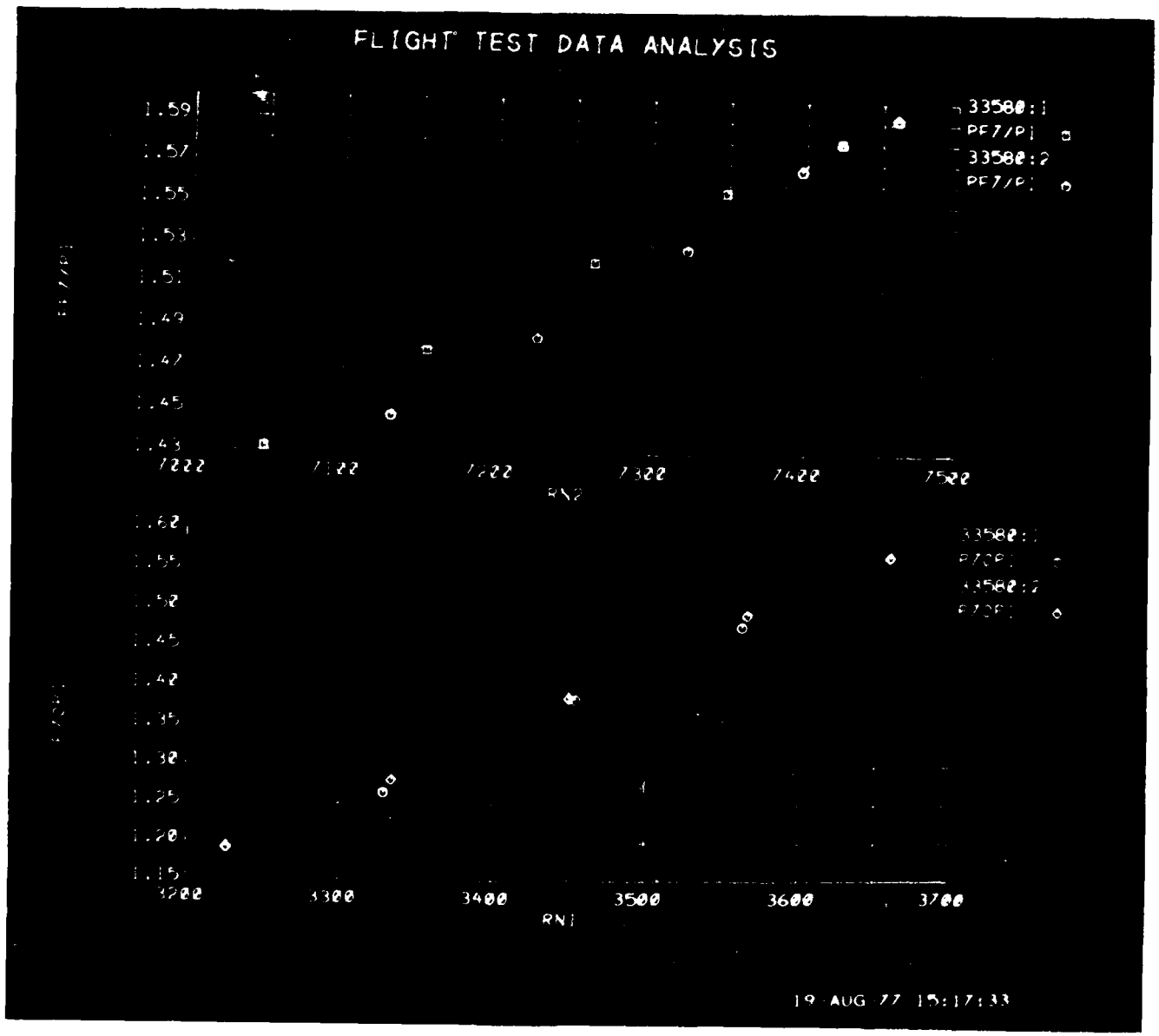
GTG9.CHT

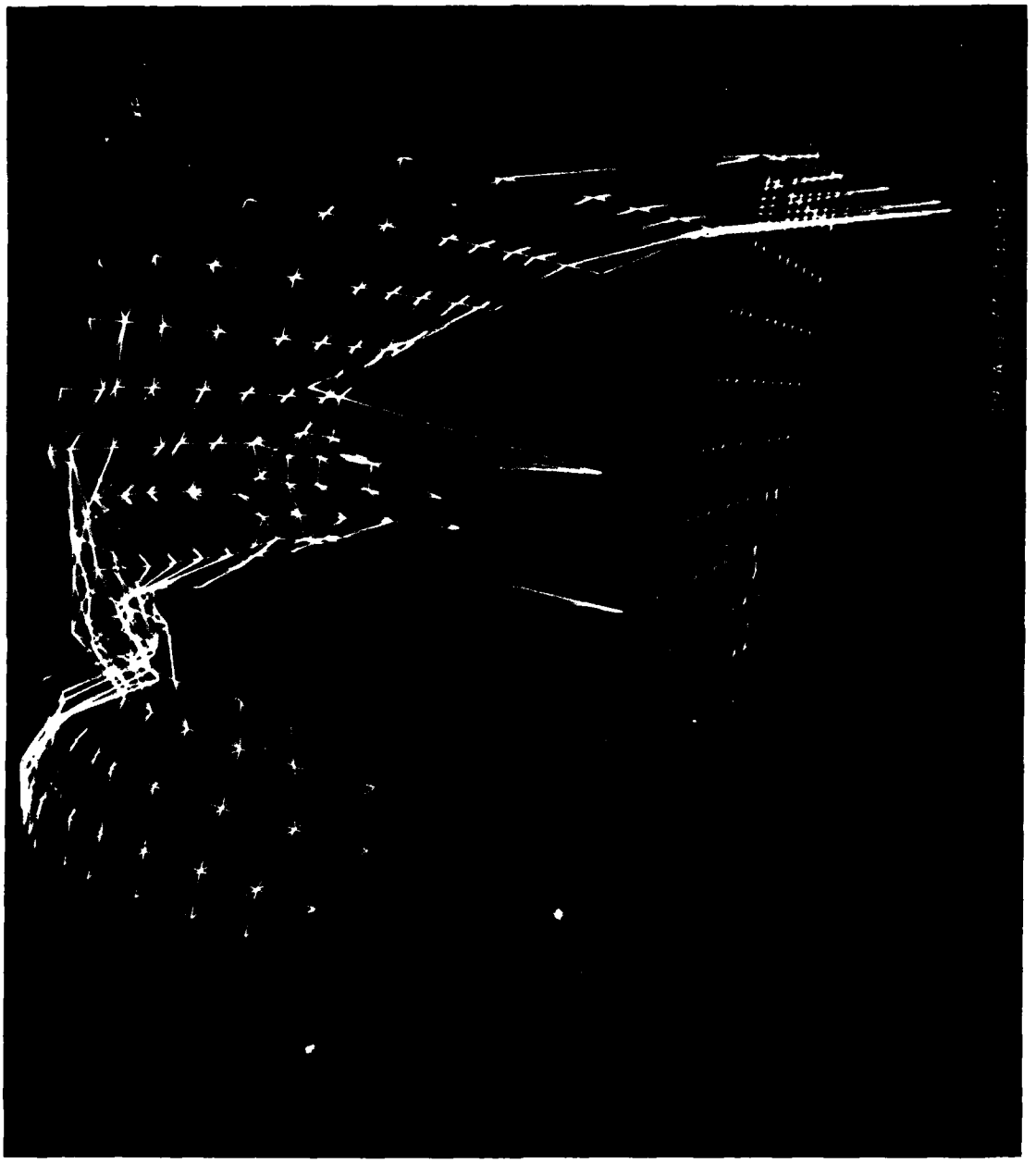
VEHICLE SYNTHESIS SIMULATION & INTEGRATION

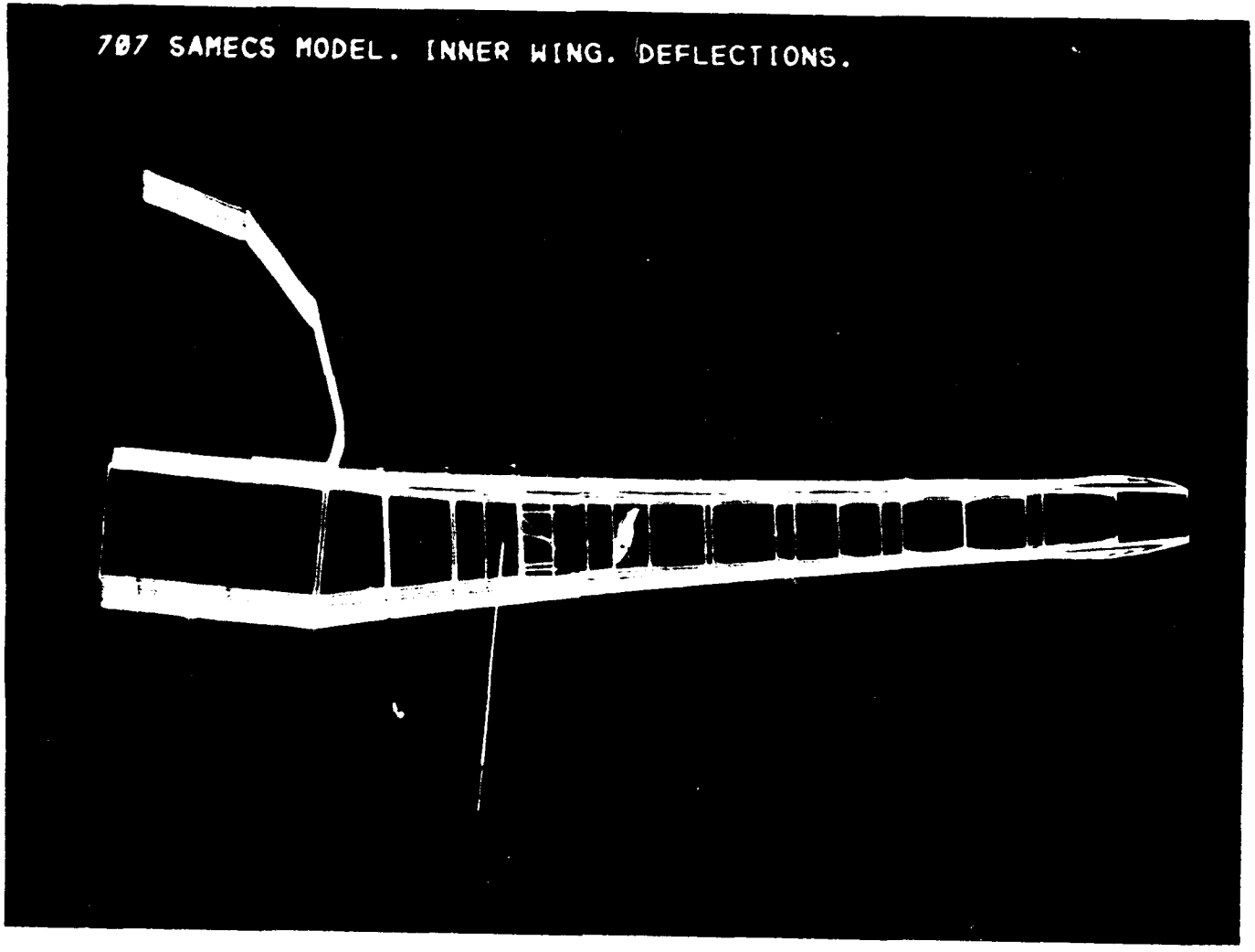


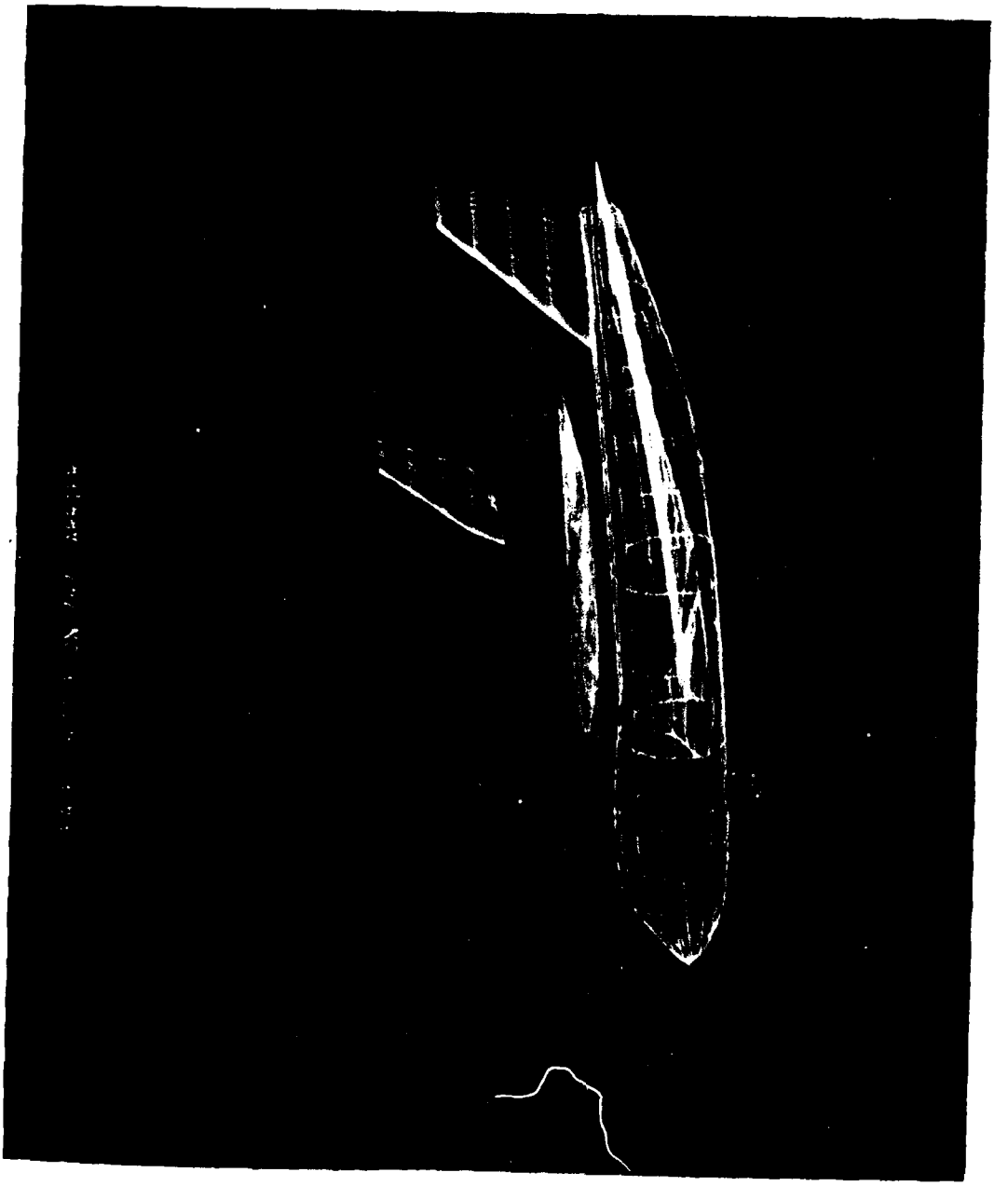


FUNCTIONAL ORGANIZATION


FLIGHT TEST DATA ANALYSIS
33580:1
PF7/P1
33580:2
PF7/P1
1.59
1.57
1.55
1.53
1.51
1.49
1.47
1.45
1.43
7222
7322
7222
7322
7422
7522
RN2
33580:1
33580:2
3200
3300
3400
3500
3600
3700
RN1
19 AUG 77 15:17:33




707 SAMECS MODEL. INNER WING. DEFLECTIONS.

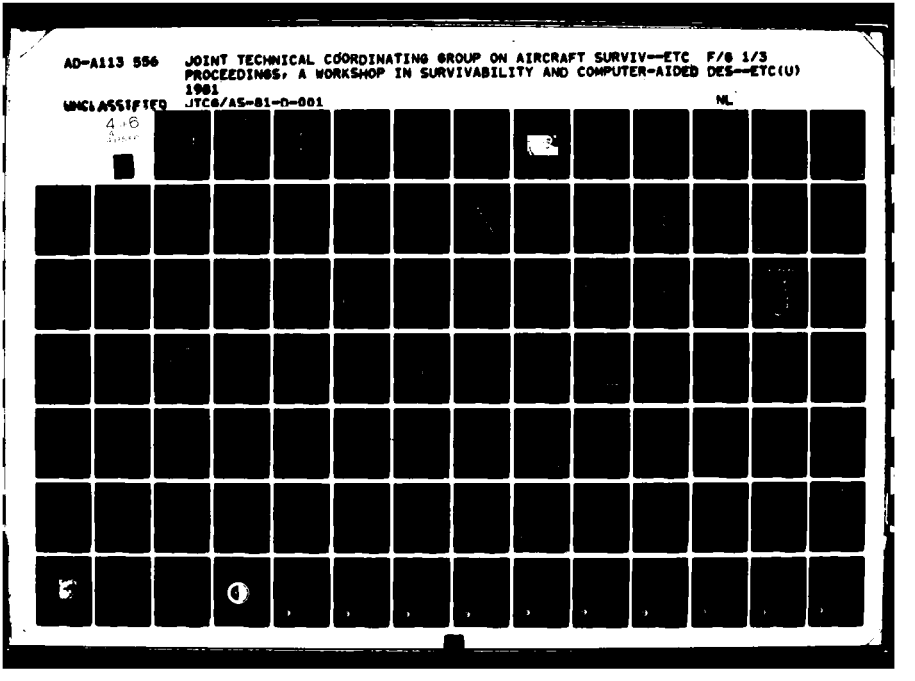


S/V & COMPUTER AIDED DESIGN

- o STATUS,
- o PLANS,
- o THOUGHTS,
- o DESIRES

AD-A113 556 JOINT TECHNICAL COORDINATING GROUP ON AIRCRAFT SURVIV--ETC F/G 1/3
PROCEEDINGS, A WORKSHOP IN SURVIVABILITY AND COMPUTER-AIDED DES--ETC(U)
1981

UNCLASSIFIED JTCG/AS-81-O-001 NL

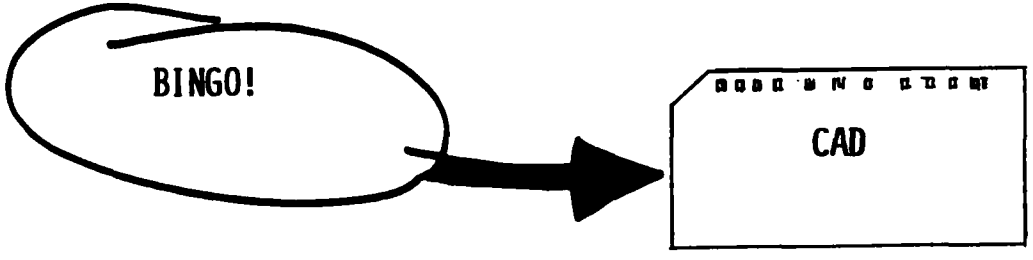


AD
A113

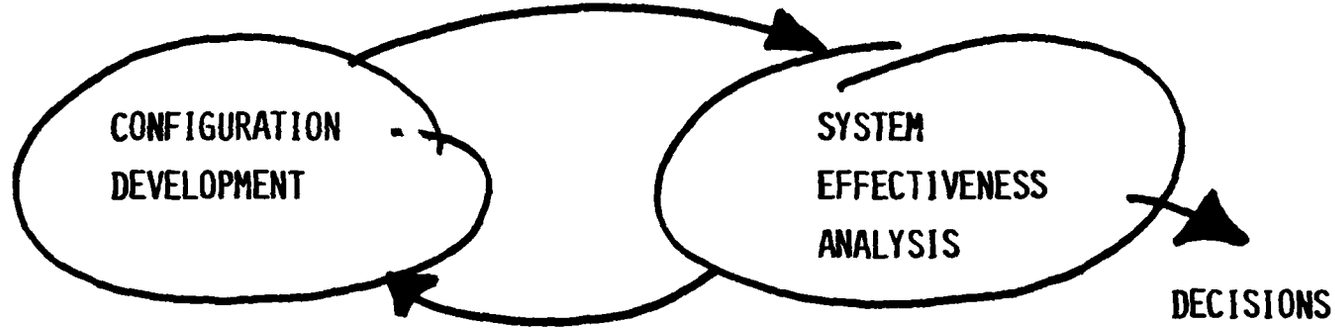
S/V & CAD ARE MADE FOR EACH OTHER

S/V TECHNOLOGISTS...

1) LIKE COMPUTERS
2) WANT TO IMPACT DESIGN



INCREASING INTERACTION BETWEEN DESIGN & EFFECTIVENESS ANALYSIS



- VULNERABILITY
  - A_V
  - LETHALITY ENVELOPES
- SUSCEPTABILITY

- MISSIONS/THREATS
- ATTRITION
- TARGETS KILLED/$
- COST BENEFIT

PROGRESSIVE VULNERABILITY ANALYSIS LEVELS

STATISTICALLY BASED SCALING MODELS → RAPID VULNERABILITY ESTIMATING METHODS → DETAILED VULNERABILITY ANALYSIS
- FASTGEN
- COVART

WHATS GOOD ABOUT CAD?

FROM THE S/V STANDPOINT...

- o THE GEOMETRY
- o THE INTERACTION
- o THE COMMON DATA BASE
- o THE PARTICIPATION

DESIRED S/V-CAD INTEGRATION FEATURES

- o VULNERABILITY/SUSCEPTABILITY MEASURES INCORPORATED AS DESIGN PARAMETERS
- o A COMMON GEOMETRIC MODEL FOR...
  - DESIGN ANALYSIS
  - VULNERABILITY/SUSCEPTABILITY ANALYSIS
- o A VULNERABILITY DATA BANK CONTAINING...
  - COMPONENT LETHALITY
  - COMPONENT SHIELDING
- o INTERACTIVE SHOTLINE ANALYSIS

LET'S NOT FORGET DETAIL DESIGN

COMPLIANCE WITH SUBSYSTEM SPECS REQUIRES...

DETAIL DESIGN ALGORITHMS FOR:

- THREAT DAMAGE
- SUBSYSTEM RESPONSE
- VULNERABILITY LEVELS

THE IMPACT OF COMPUTER GRAPHICS ON PRODUCT DEVELOPMENT

Richard Ricci
Lockheed-California Company
Burbank, California

THE IMPACT OF COMPUTER GRAPHICS ON PRODUCT DEVELOPMENT

Richard Ricci
Lockheed-California Company
Burbank, California

Interactive computer graphics development was started at the Lockheed-California Company during the mid-1960s. After several years, this initial development matured into a design drafting package called the CADAM* System. This system has continued to be expanded, and other graphic applications have been integrated with its data base until nearly all aspects of aircraft design have been considered.

CADAM is now used extensively at all major Lockheed companies, including the Lockheed Georgia and Lockheed Missiles and Space Companies as well as the California Company (CALAC). It has also been licensed for use and enjoys wide acceptance as a design/drafting tool throughout the world.

Computer Graphics at CALAC, specifically the CADAM system, is now being used throughout the design Corporation process--from conceptual design through final product support data in the form of maintenance manuals.

In the conceptual, preliminary, and derivative design phase, the graphics system is used to first develop the basic three-view general arrangement drawing. From this information analysis, data models can be generated semi-automatically for input to batch computing mission analysis and aerodynamic programs. These programs perform optimization analysis on the basic aircraft shape and size. This data is fed back to the designer who then modifies the basic configuration as necessary. Also done on the graphics cathode ray tube (CRT) during these early phases of design are interior sizing to satisfy various cargo, passenger and equipment requirements. Once the basic shape has been determined, the designer can generate an air swept (lofted) surface definition of the vehicle and a "structural arrangement" layout. These are used for wind tunnel modeling and structural analysis.

The applications of CADAM in the production design areas of CALAC have been extensive and permeate nearly all areas of engineering. The variety of capability covers such diverse disciplines as airframes, interiors,

* Registered trademark of the Lockheed

instrument layouts, mechanisms layouts and motion studies, hydraulic schematics, electrical design, and paint and markings. Virtually no area remains untouched by graphics. However, much of the current design efforts are still manual. This is mainly because of training requirements of both new and old employees, hardware requirements, and acceptance by middle management.

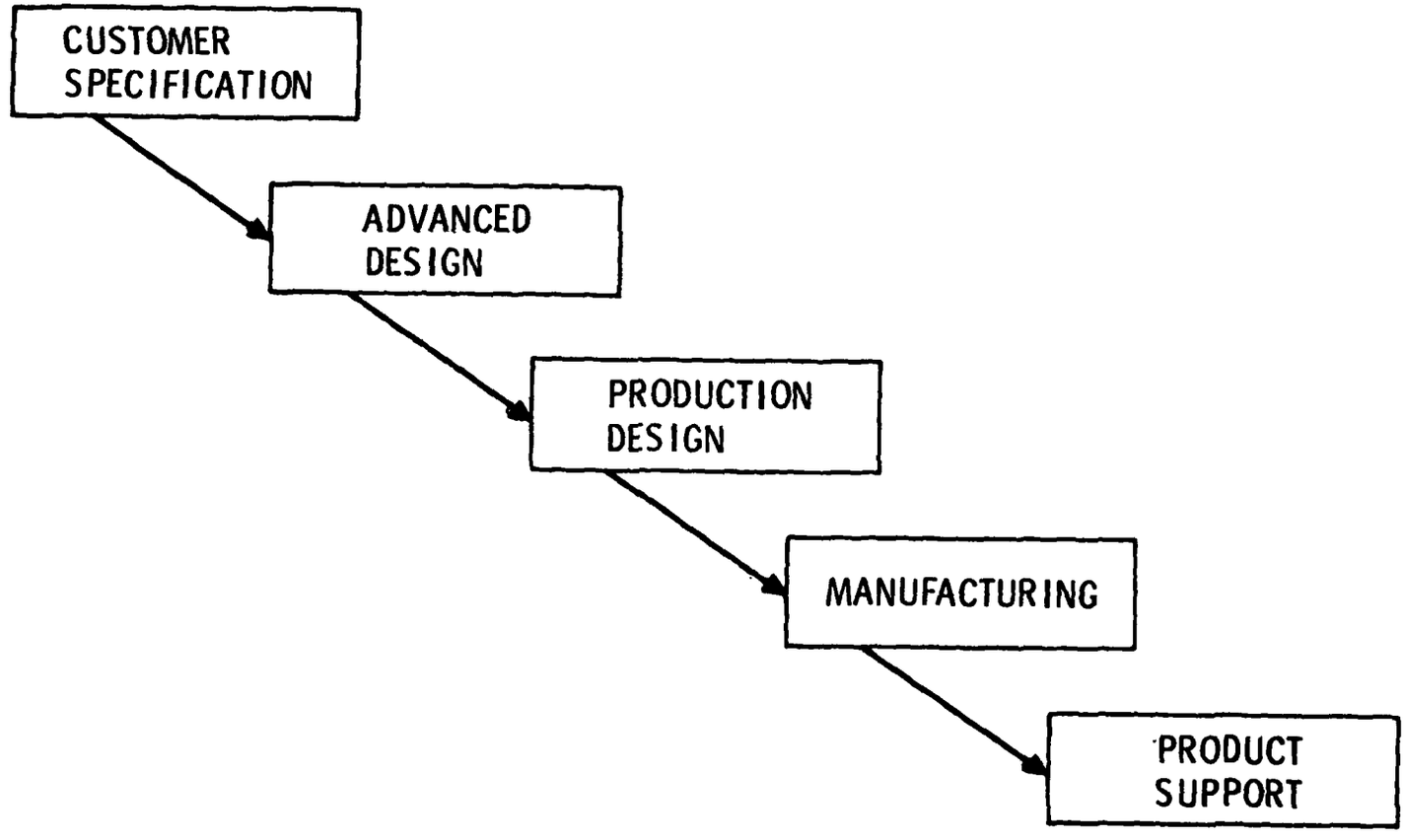
CADAM's use in the manufacturing area of the company ranks among the oldest and most established. Manufacturing began using the system back in 1968 for the programming and generation of numerical control (NC) machine tapes. Today virtually 100 percent of all NC tapes made at Lockheed are done by graphics. In addition to this activity, the tool design and Quality Assurance areas of manufacturing are also now using the system.

Finally, but certainly not least, is the application of graphics in the product support area. These are the people who develop and maintain maintenance manuals. At CALAC this is a 100 percent CADAM endeavor on the L-1011 Trijet project. The size of the task is so large that their current data base is well over 250,000 drawings.

Other major areas of graphics include lofting and analysis modeling. One hundred percent of all CALAC loft data are now generated on graphics. In the analysis modeling area extensive use is being made of the existing and newly created geometry drawings to develop analytical models such as aerodynamic paneling models, finite element models, and survivability assessment models.

THE IMPACT OF COMPUTER GRAPHICS ON PRODUCT DEVELOPMENT AT LOCKHEED CALIFORNIA

THE PROCESS


CUSTOMER SPECIFICATION
ADVANCED DESIGN
PRODUCTION DESIGN
MANUFACTURING
PRODUCT SUPPORT

APPLICATION OF CADAM IN CONCEPTUAL AND PRELIMINARY DESIGN

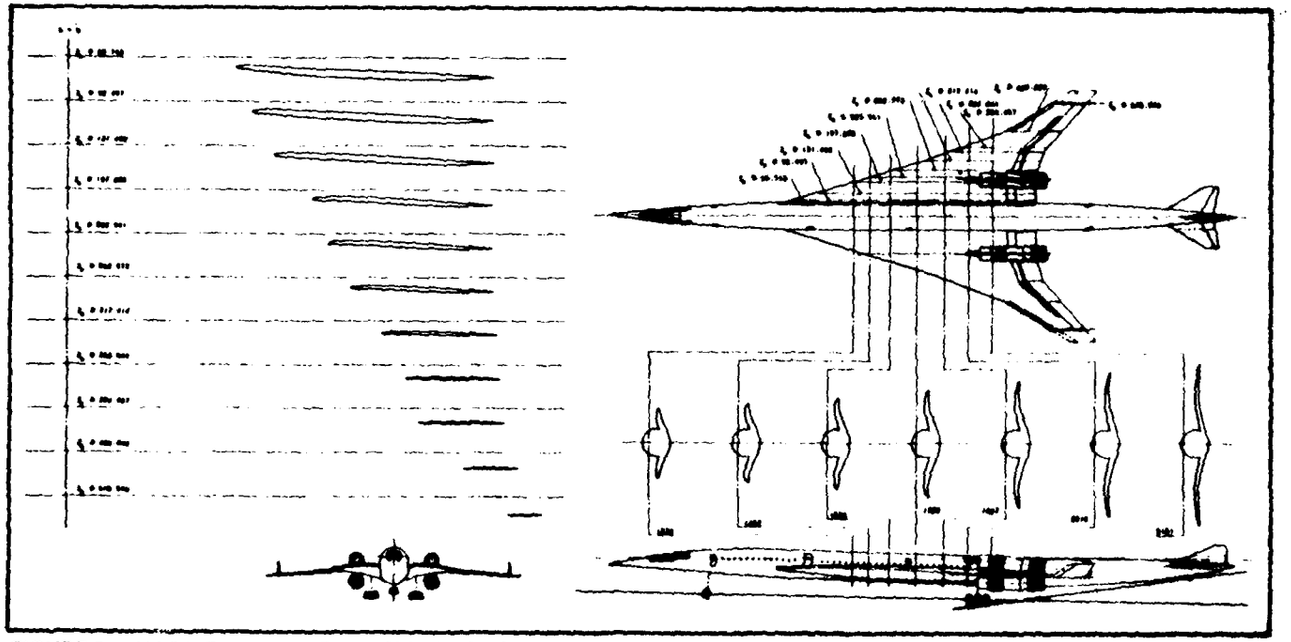


FIGURE 7 NASA Supersonic Cruise Vehicle Configuration Drawing Made With the CADAM System

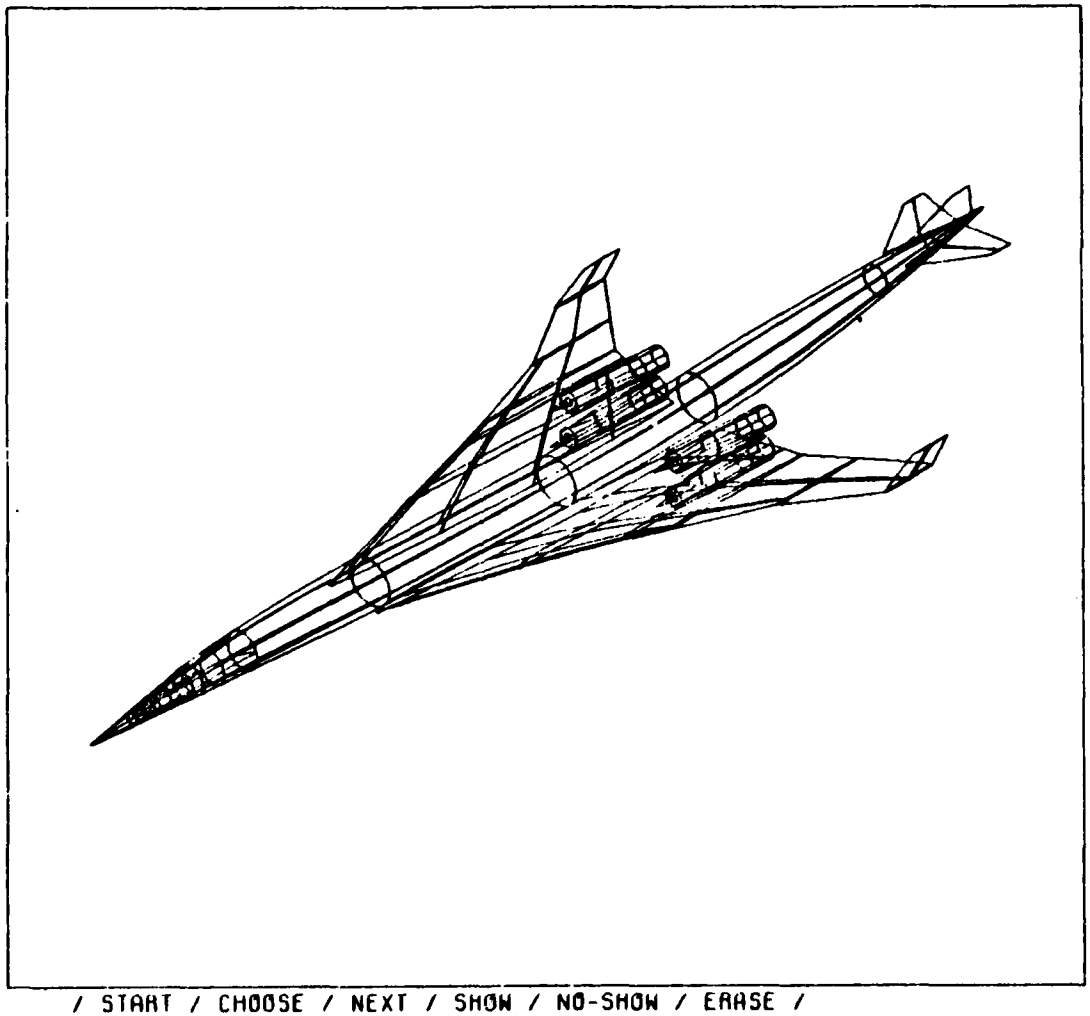
VIEW PV SCL .010 WDO 2.000,.0
SEL PARAMETER TO MODIFY

ID=

GENDATA		FUEL		GENERAL	
GROSS WT	=496000.000	CFVBOX		*WING INC	=3.000
THRUST	=50000.000	CSECTB		THRUST A	=.000
WOS	=140.000	FVOL		SCRAPE A	=12.124
TOW	=.300	WING REF		GRDRUN A	=12.124
MACH NO	=.830	WTANK1		GEAR-LEN	=140.889
ALT	=35000.000	WTANK2			
CREW	=11.000	FVFB			
PASS	=246.000	VFB		PROPULSN	
PAYLOAD	=91300.000			NENG	=2.000
FUEL	=213600.000			REFTHRST	=50000.000
				ENGSCL	=1.000
HTAIL		VTAIL		LENG	=162.815
S-H	=184844.812	S-V	=78663.062	DENG	=96.001
AR-H	=3.980	AR-V	=1.610	YINBD	=411.339
TR-H	=.330	TR-V	=.300	YOUTBD	
SWPL-H	=39.593	SWPL-V	=40.969		
SWPQ-H	=35.036	SWPQ-V	=35.000		
B-H	=857.581	B-V	=356.000	TYPE-I	=3.000
CR-H	=322.995	CR-V	=340.666	LINLET	=42.146
CT-H	=105.972	CT-V	=101.262	*SWET-I	=12746.000
MAC-H	=232.164	MAC-V	=242.581		
TOC-H	=.076	TOC-V	=.099		
X-H	=133.237	X-V	=75.345	N NAC	=2.000
Y-H	=76.644	Z-V	=.000	LNAC	=204.961
XCP-H	=120.894	XCP-V	=153.369	DMAXNAC	=108.261
*SEXP-H	=139932.000	SEXP-V	=78663.062	SWETNAC	=43624.000
SWET-H	=286133.000	SWET-V	=160850.000	VOLNAC	=1298473.00
VOL-H	=1489372.00	VOL-V	=1471415.00	TOCNAC	=2.280
				LAVGPYL	=312.000
				HAVGPYL	=33.156
				SPLANPYL	=10344.605
				SWETPYL	=21517.000
				VOLPYL	=86538.000
				TOCPYL	=6.600

/ FWD / BACK / WING TABLE / RETURN /

ORIGIN VIEW PV SCL .010 WDO 2.500,.0

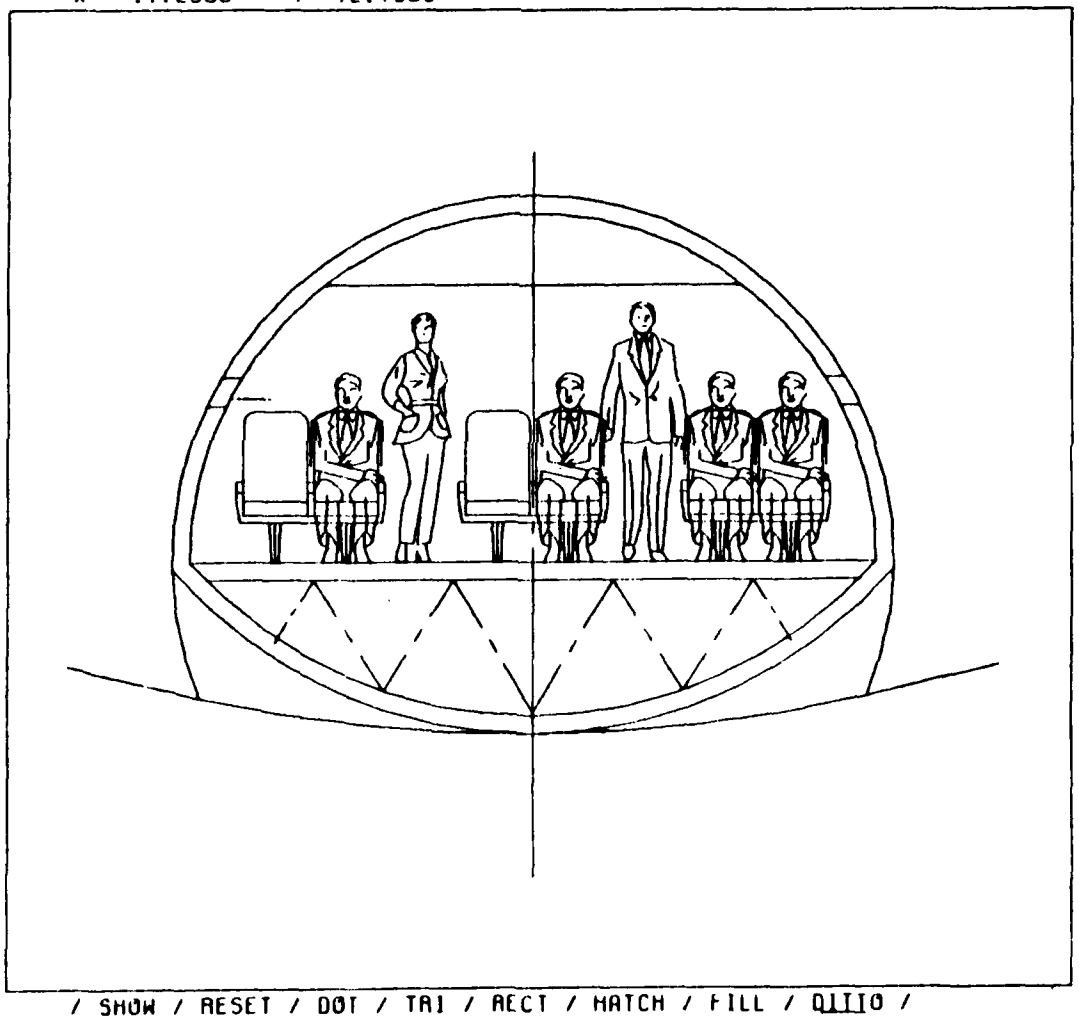


/ START / CHOOSE / NEXT / SHOW / NO-SHOW / ERASE /

MISC-2 VIEW F SCL .020 WDO .500 ,.0

DEFINE PIVOT

X= -17.2500 Y= 72.7303

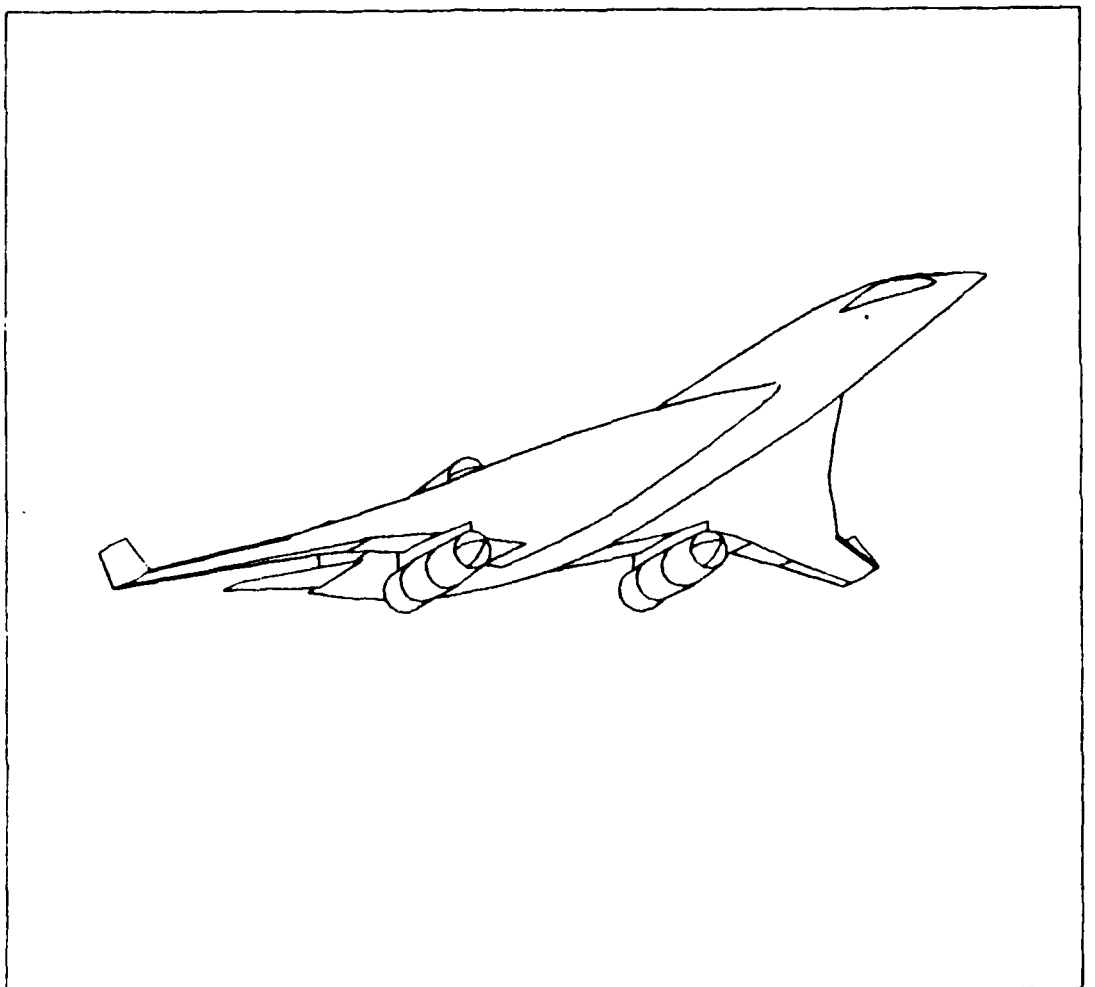


/ SHOW / RESET / DOT / TRI / RECT / HATCH / FILL / QUIO /

TYPE

VIEW IS SCL .010 WDO 1.500,.0

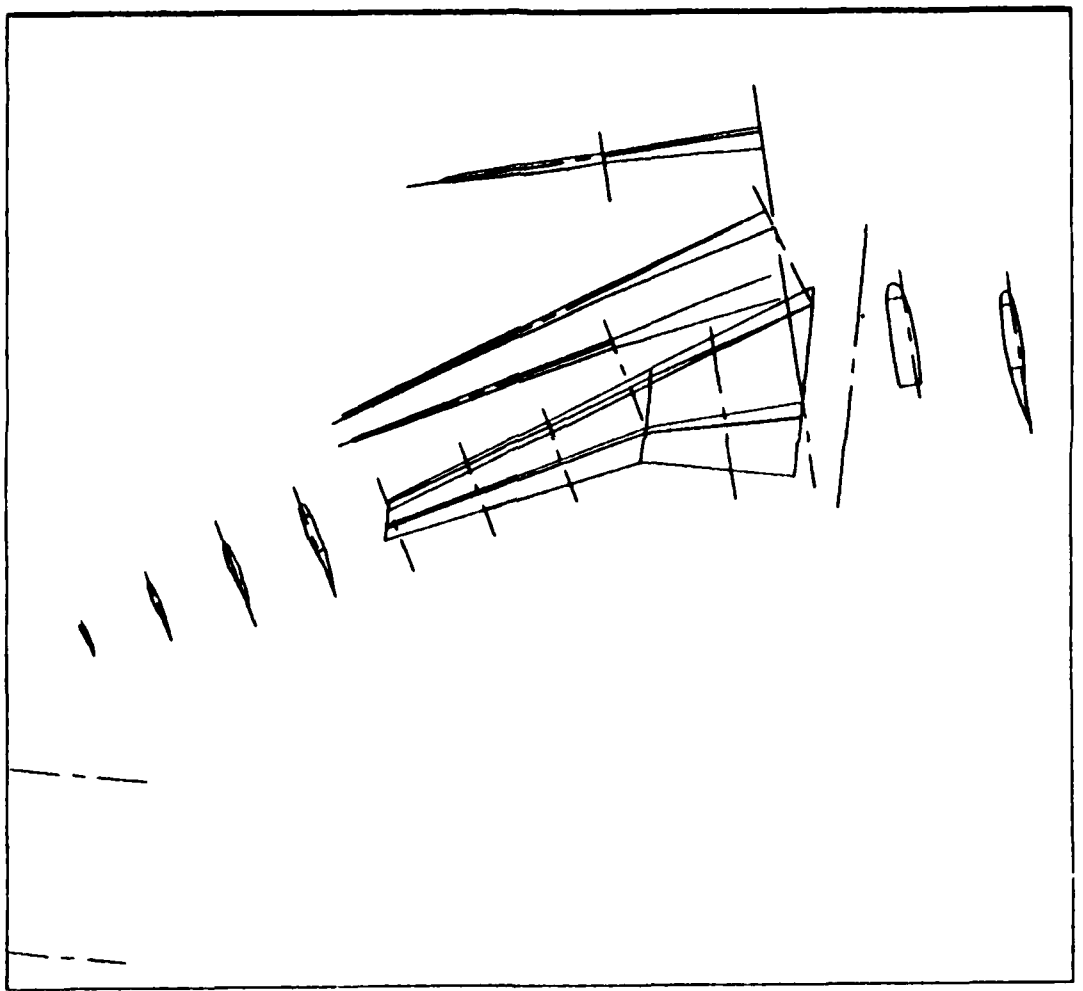
SEL ANY



/ SOLID / DASH / CL / PHAN / NC / BAK // H / M / L //SHOW/RESET/

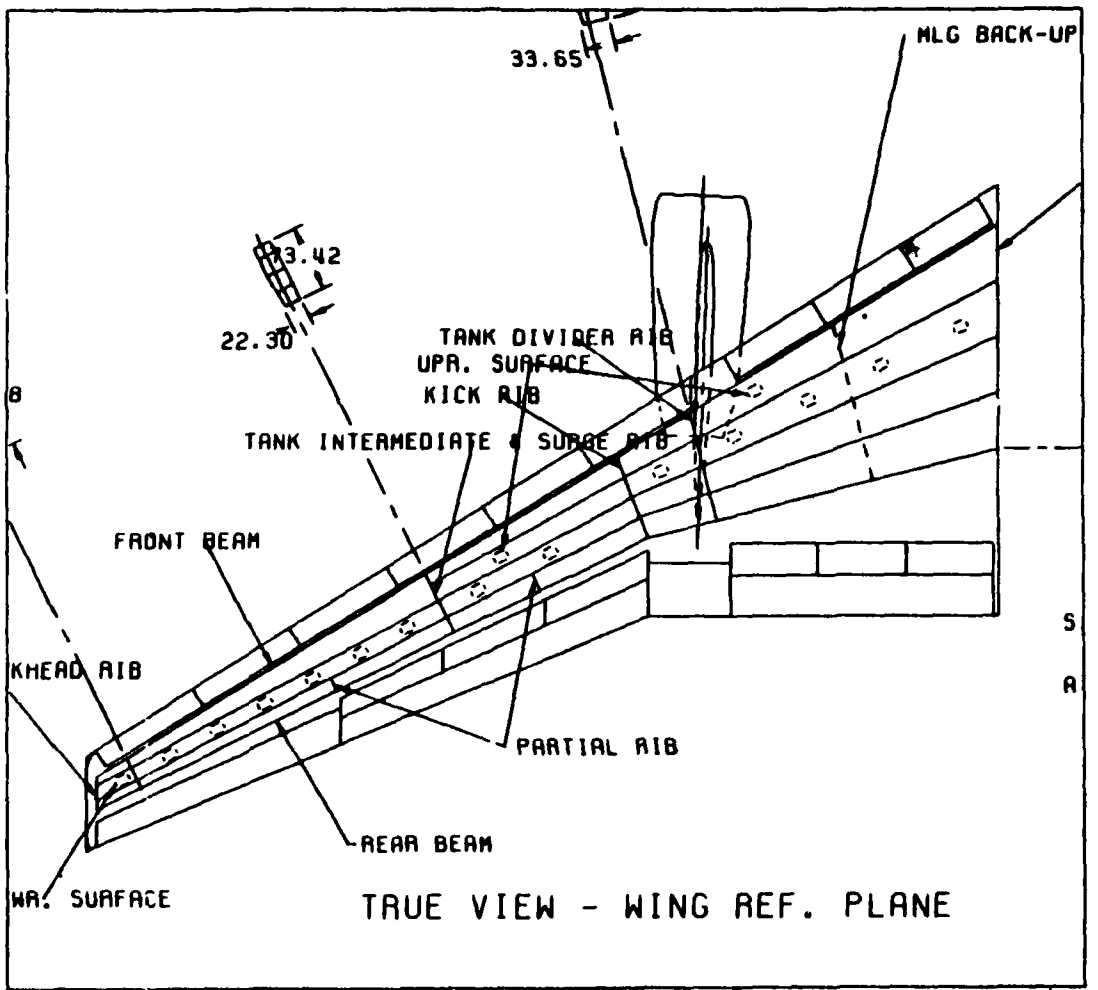
SHOW

VIEW PV SCL .020 WDO 4.500,.0
SEL ANT,Y/N ERASE GROUP



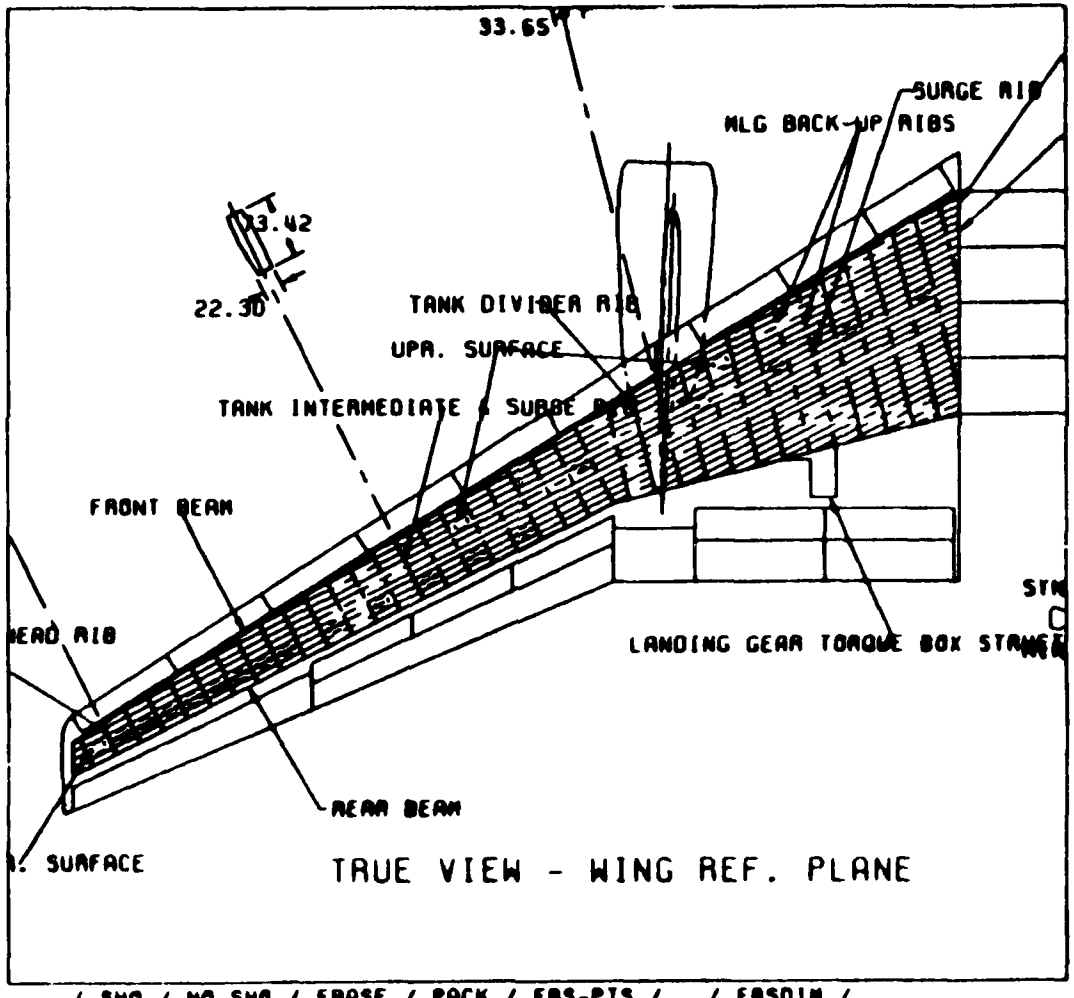
/ SHO / NO-SHO / ERASE / PACK / ERS-PTS / / ERSDIM /

VIEW PV SCL .020 WDO 2.000,.0

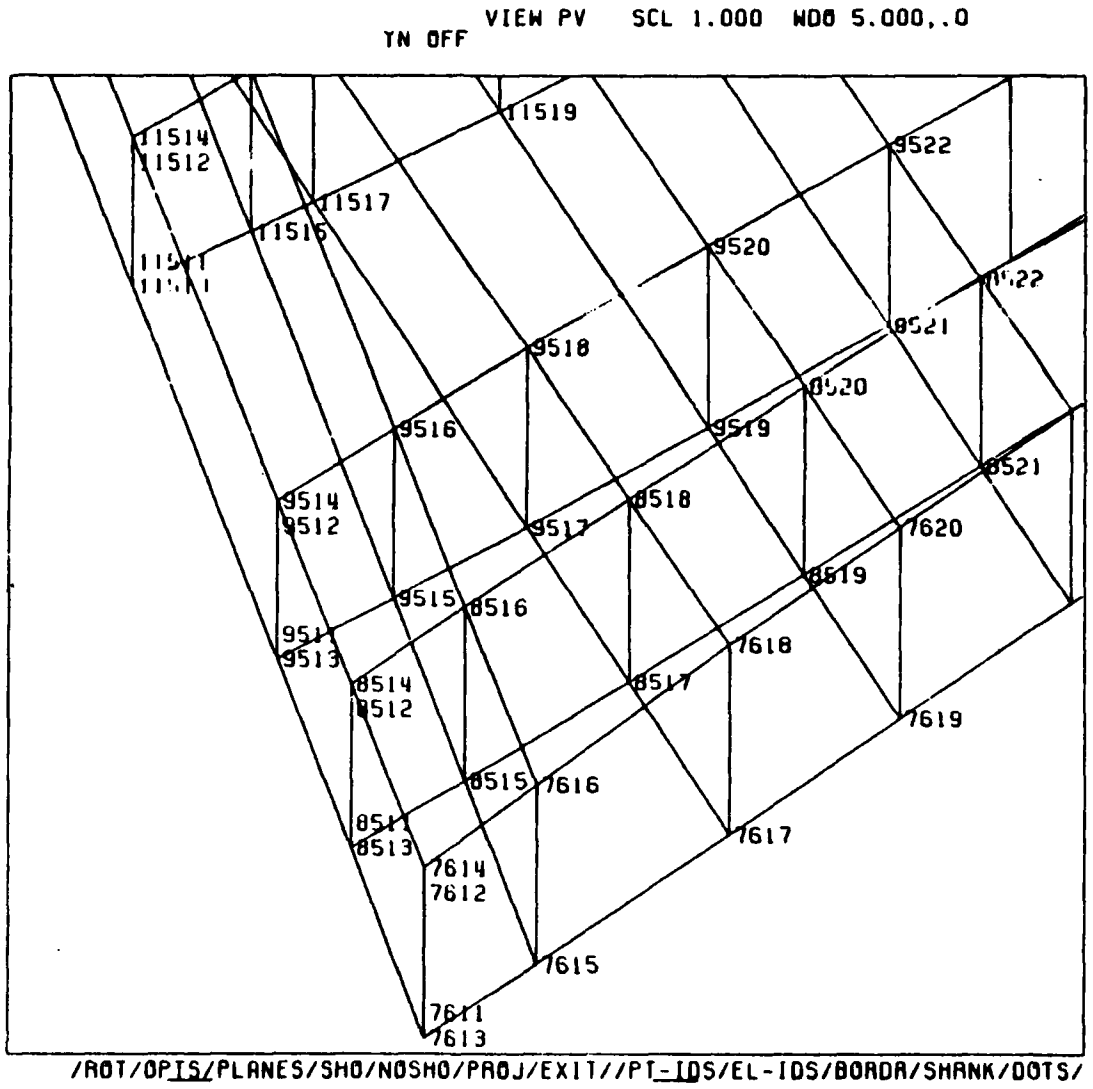


/ PLOT1 / PLOT3 / FILM / WINDOW / NEW FRAME / OLD FRAME / ELECTRO /

SHOW VIEW PV SCL .020 MOD 2.000,.0
SEL ANT.T/N ERASE GROUP



/ SHO / NO-SHO / ERASE / PACK / ERS-PTS / / ERSDIM /


TN OFF
VIEW PV SCL 1.000 WDO 5.000,.0
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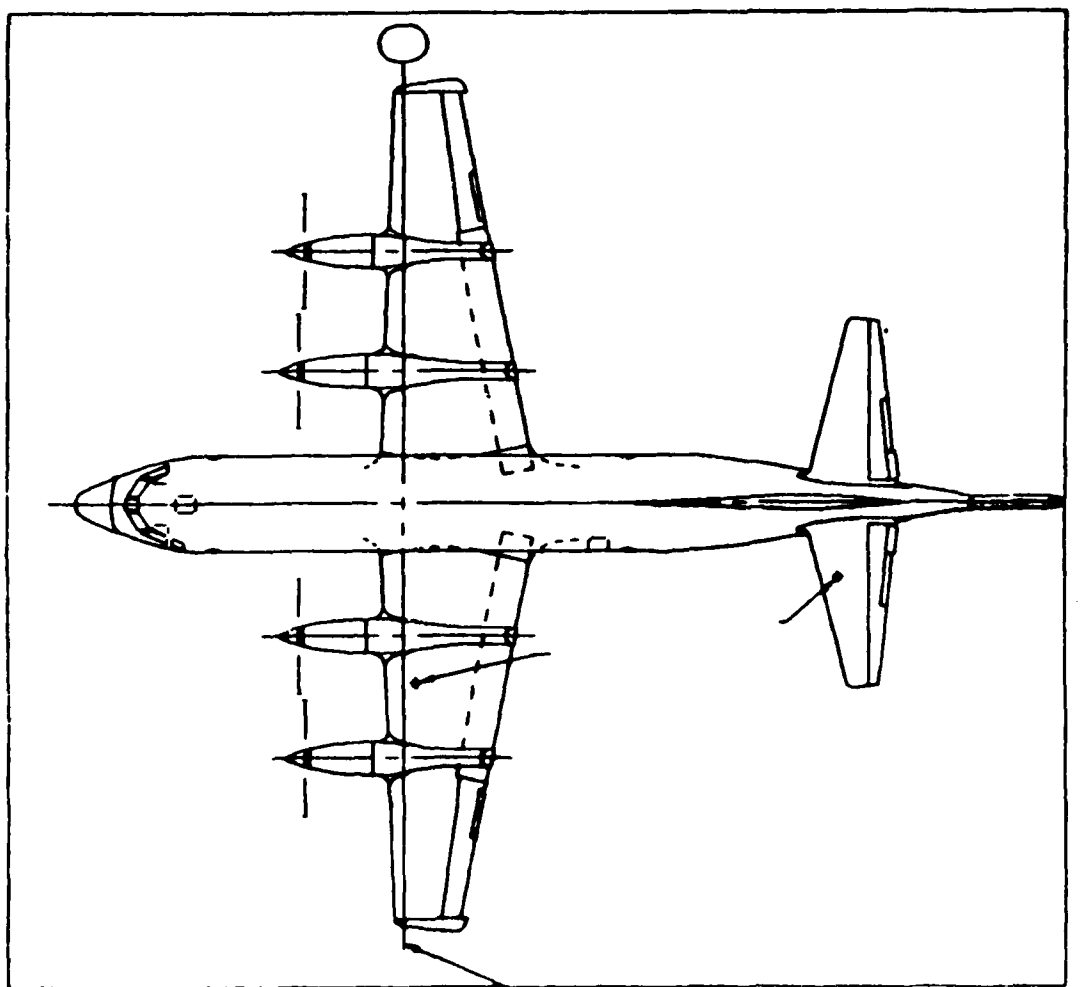
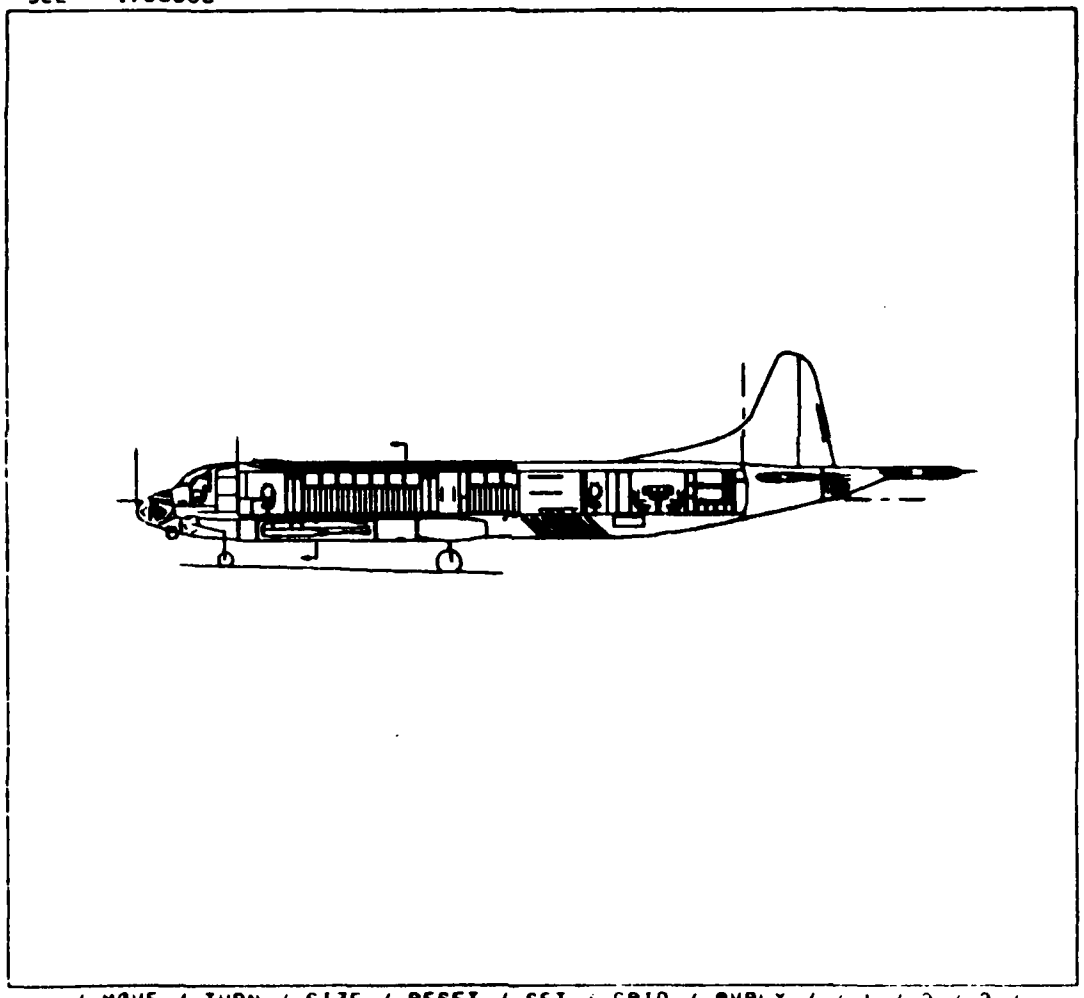
VIEW PV SCL .020 WDO 2.500..0



/ PLOT1 / PLOT3 / FILM / WINDOW / NEW FRAME / OLD FRAME / ELECTRO /

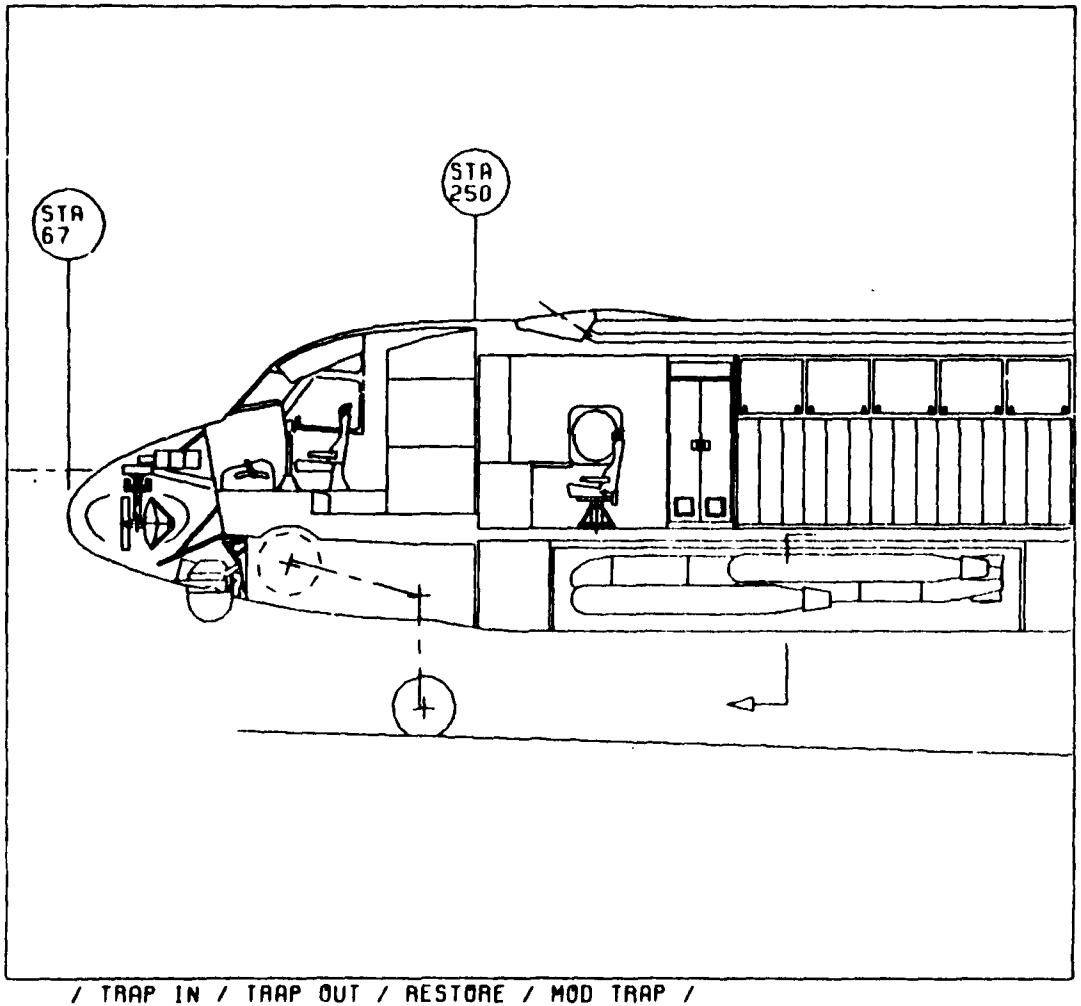
WINDOW VIEW PV SCL .025 WDO 4.000,.0
IND SIZE / KEY SIZE / KEY X,Y,SIZE / SEL ANT TO MOVE / TN SIZE=1
SCL = 4.00000



/ MOVE / TURN / SIZE / RESET / SET / GRID / OVRLY / / 1 / 2 / 3 /

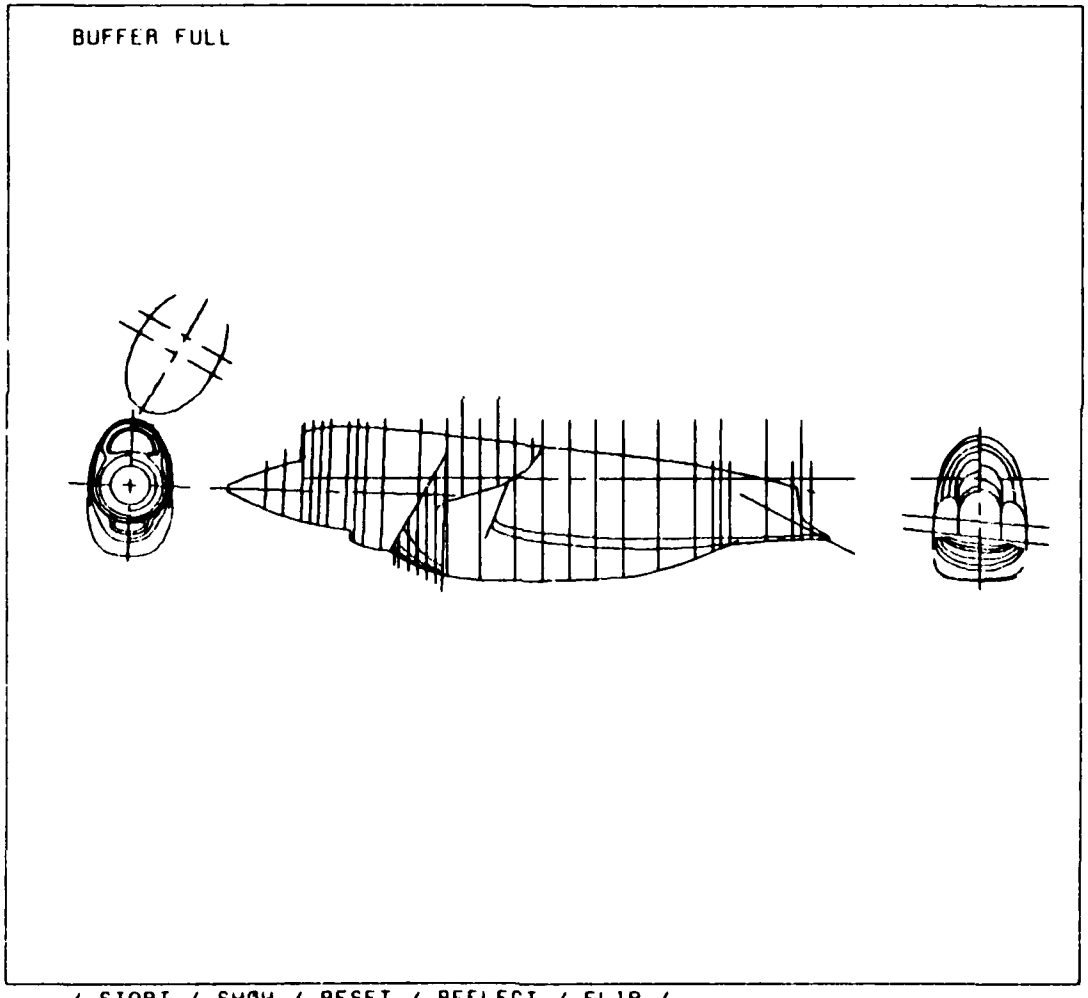
GROUP

VIEW PV SCL .025 WDO 1.000,.0
SEL PT / IND PT / TN BACKUP



/ TRAP IN / TRAP OUT / RESTORE / MOD TRAP /

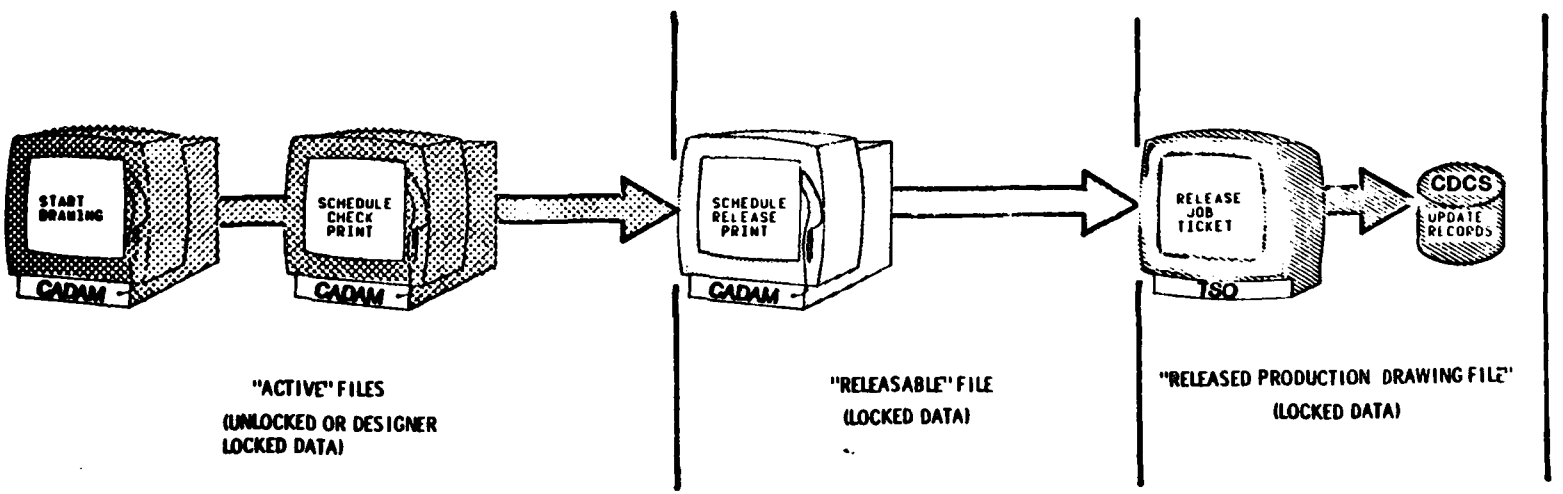
GROUP VIEW PV SCL .100 WDO 5.000,.0
SEL MIRROR LINE 1



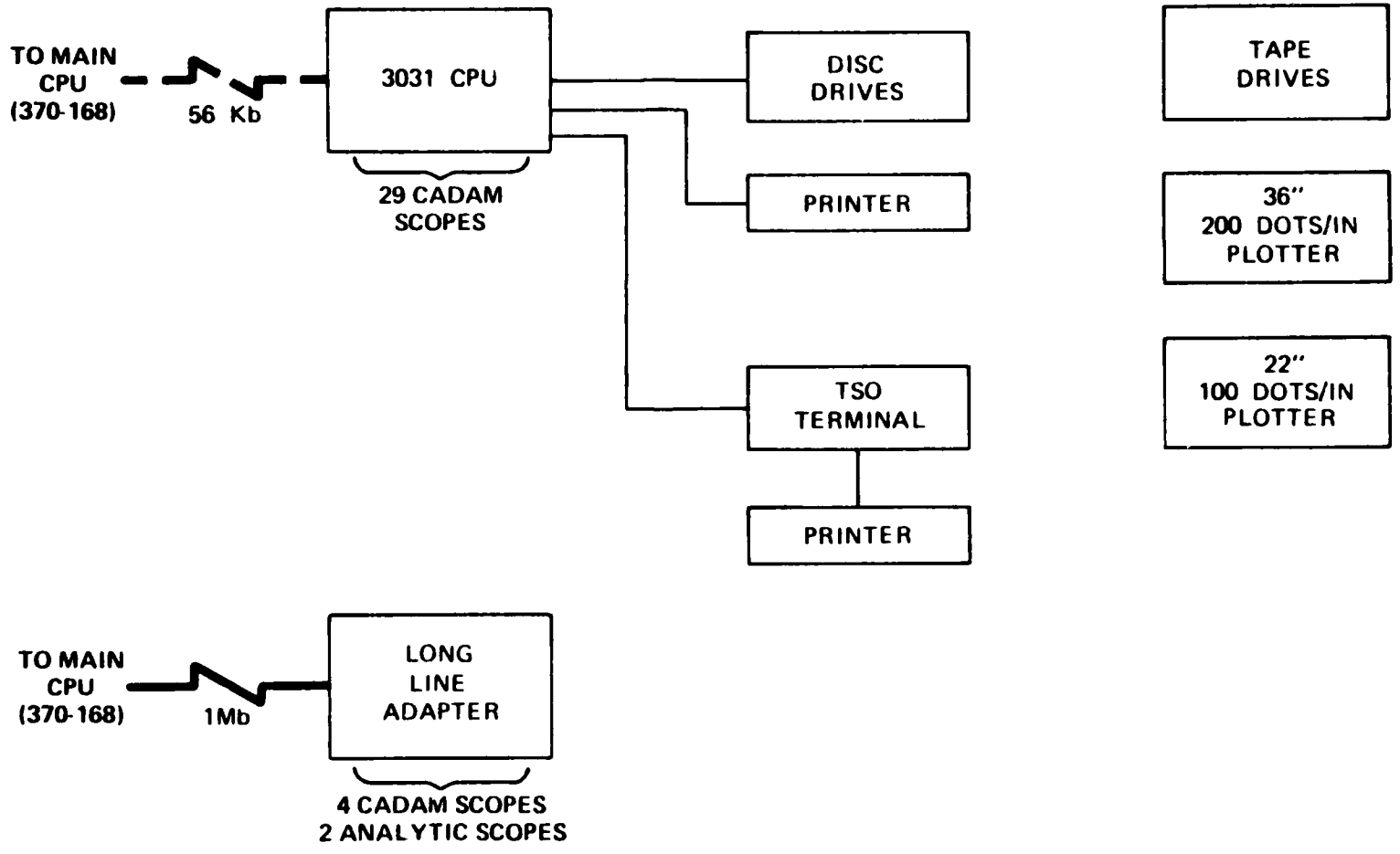
/ START / SHOW / RESET / REFLECT / FLIP /

APPLICATION OF CADAM IN PRODUCTION DESIGN

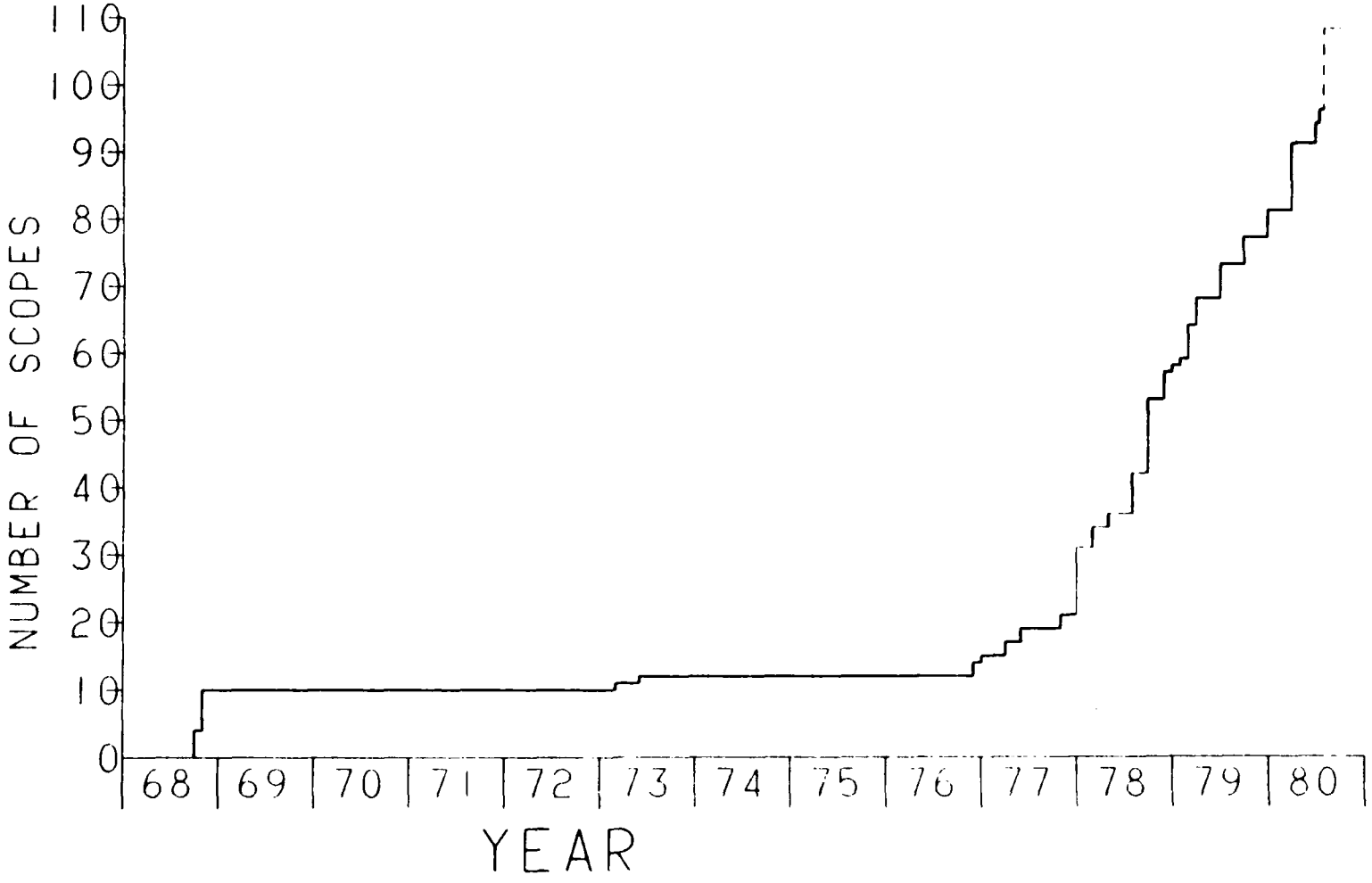
CADAM DRAWING CONTROL SYSTEM



PRODUCTION DESIGN CADAM COMPLEX



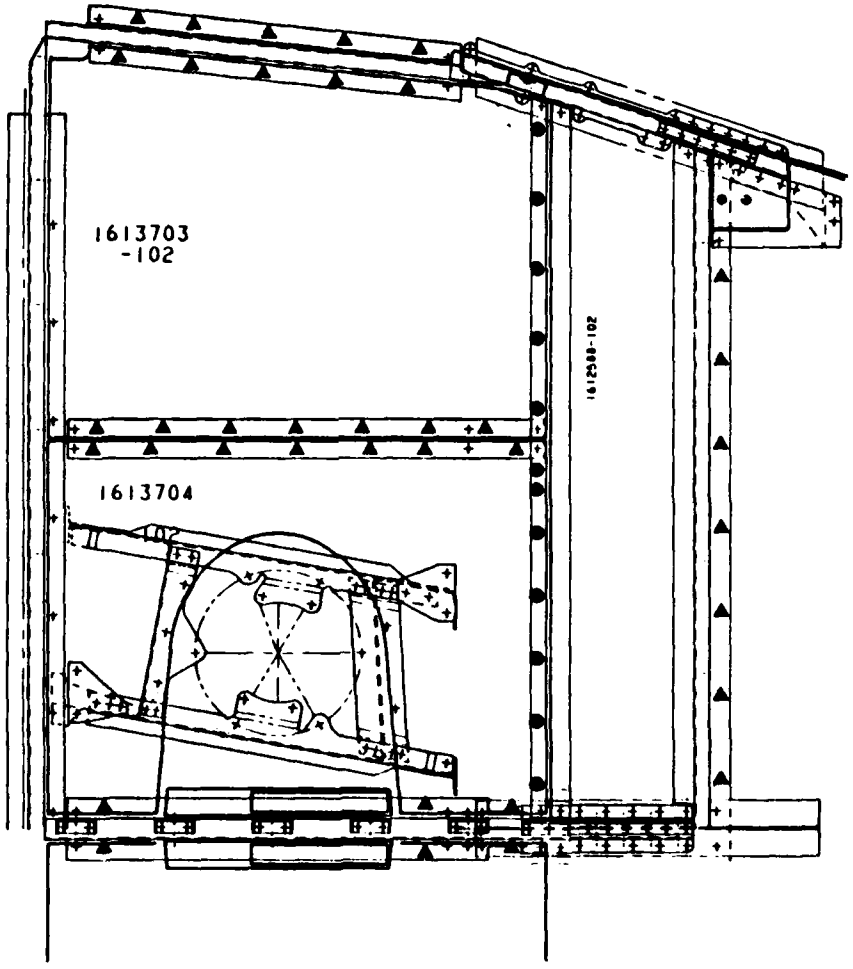
SCOPE GROWTH AT CALAC



TYPES OF DESIGNS

- AIRFRAME
  - L.E.SLATS
  - FLOOR STRUCTURE
  - RIBS
  - DOOR SEALS
  - FAIRINGS
- INTERIOR ARRANGEMENTS
- INTERIOR DESIGN
  - FLOOR BOARDS
    - CARPETS
  - GALLEYS
  - LAVATORIES
  - CLOSETS
  - CLASS DIVIDERS
- INSTRUMENT PANELS
  - INSTALLATIONS
    - ASSEMBLIES/DETAILS
- MECHANISM LAYOUTS
  - ELEVATOR MECHANISMS
  - LANDING GEARS
  - POWER DRIVE UNITS
  - AILERON FEEDBACK LINKAGE
  - SPOILER INPUT LINKAGE
- HYDRAULIC SCHEMATICS
- ELECTRICAL DESIGN
- ANTENNA INSTALLATIONS
- PAINT & MARKINGS
- STD LIBRARY

FLOORBOARD SUPPORT STRUCTURE

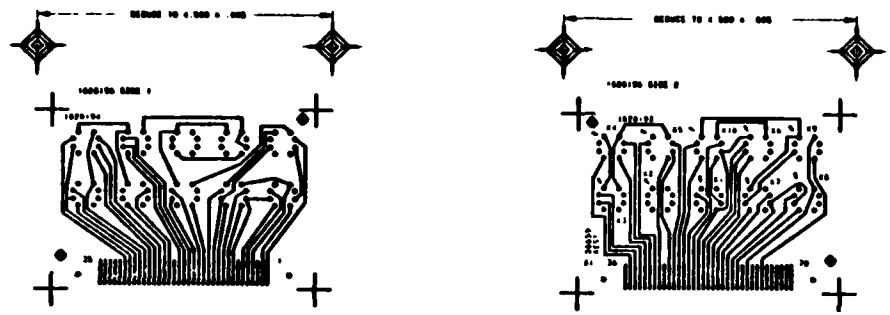


CADAM PREPARED PC BOARD

THIS DATA CONTAINS INFORMATION AND/OR DESIGNS WHICH ARE THE PROPERTY OF LOCKHEED CORPORATION. RECIPIENT, BY ACCEPTING THE SAME, AGREES THAT THE DATA WILL NOT BE REPRODUCED, TRANSFERRED TO OTHER DOCUMENTS, DISCLOSED OUTSIDE OF THE RECIPIENT ORGANIZATION, OR USED FOR MANUFACTURING OR PROCUREMENT WITHOUT THE EXPRESS WRITTEN PERMISSION OF LOCKHEED CORPORATION

REVISIONS

ZONE	LTR	DESCRIPTION	DFTSMN	DATE	APPROVED



(2) SEE CDAR FOR SIGNATURES

1. THIS DRAWING WAS PRODUCED BY COMPUTER-GRAPHICS NOT TO BE MANUALLY CHANGED

NOTES:

UNDIMENSIONED DRAWING THIS COPY FOR REFERENCE ONLY

FN	QTY DASH	QTY DASH	QTY DASH	QTY DASH	QTY DASH	QTY DASH	SYM	FSCM NO.	PART OR IDENTIFYING NO.	NOMENCLATURE OR DESCRIPTION	ZONES SH/DES	LTD HIST SCHED	MATL SPEC OR REF DOC	MATL, NOTE SYM OR REF DES	SIZE OR SHAPE	FINAL CONDTN
	QTY REQD PER DASH NO.															

PARTS LIST

QTY/NHA	QTY/CIC	TRVLG DASH NO	NEXT ASSY	USED ON	CIC	FROM	THRU	CIC VAR CODE
			1628194	L-1011				

INITIAL APPLICATION (USAGE) DATA - NOT MAINTAINED

EFFECTIVITY DATA

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES

TOLERANCES ON

FRACTION	DECIMAL	ANGLE
±	± .03	±

MATL DR

STRESS

VALUE ENGR

WT

CONTR LCPF

DATE 4-12-79

PREPARED D. CLARKE

CHECKED

SUPERVISOR P. FOLEY

MAINT

LOCKHEED APPV (2)

APPROVAL

SCALE 1/1

LOCKHEED-CALIFORNIA COMPANY
BURBANK CALIFORNIA
A DIVISION OF LOCKHEED AIRCRAFT CORPORATION

MASTER PATTERN
HEADING COUPLER BD 1

SIZE	FSCM NO	DRAWING NO.
C	36659	1628196

CALC WT LB SHEET 1 OF 1

LATEST CHG. JOB NO.

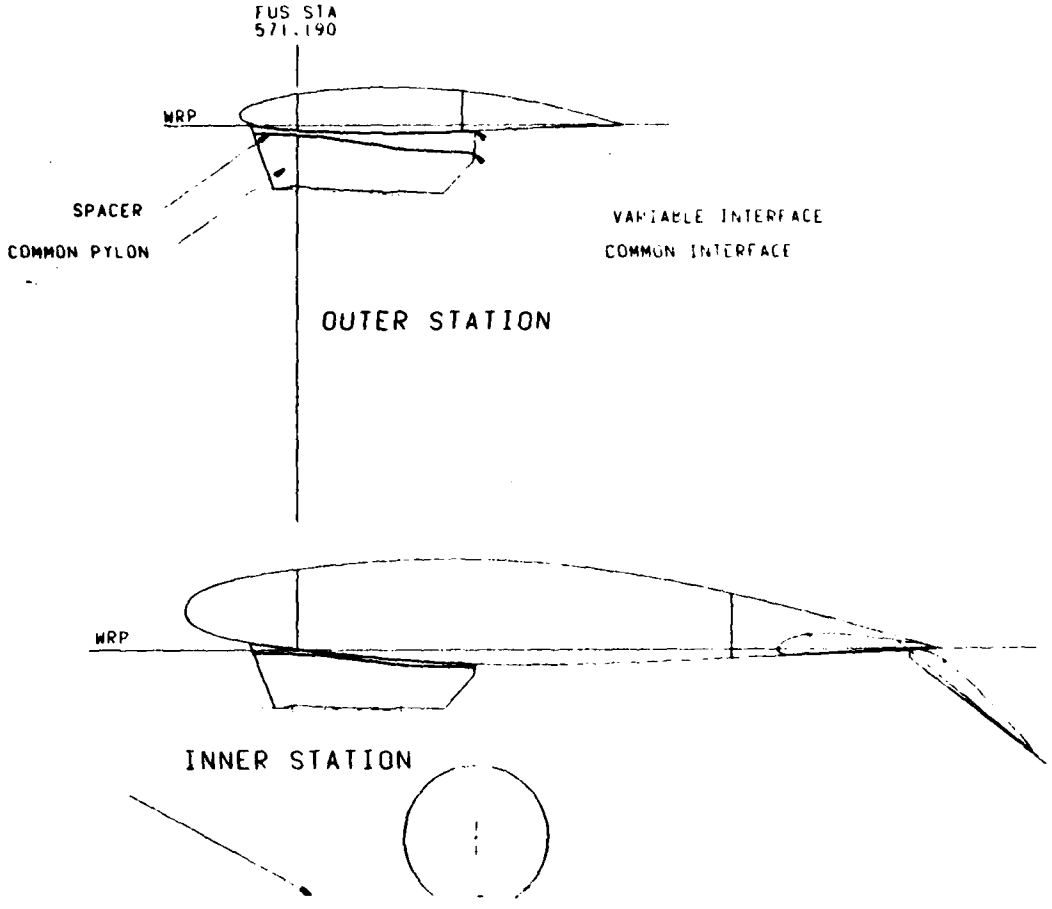
CG 1628196

ORIG JOB NO. LVFG0032

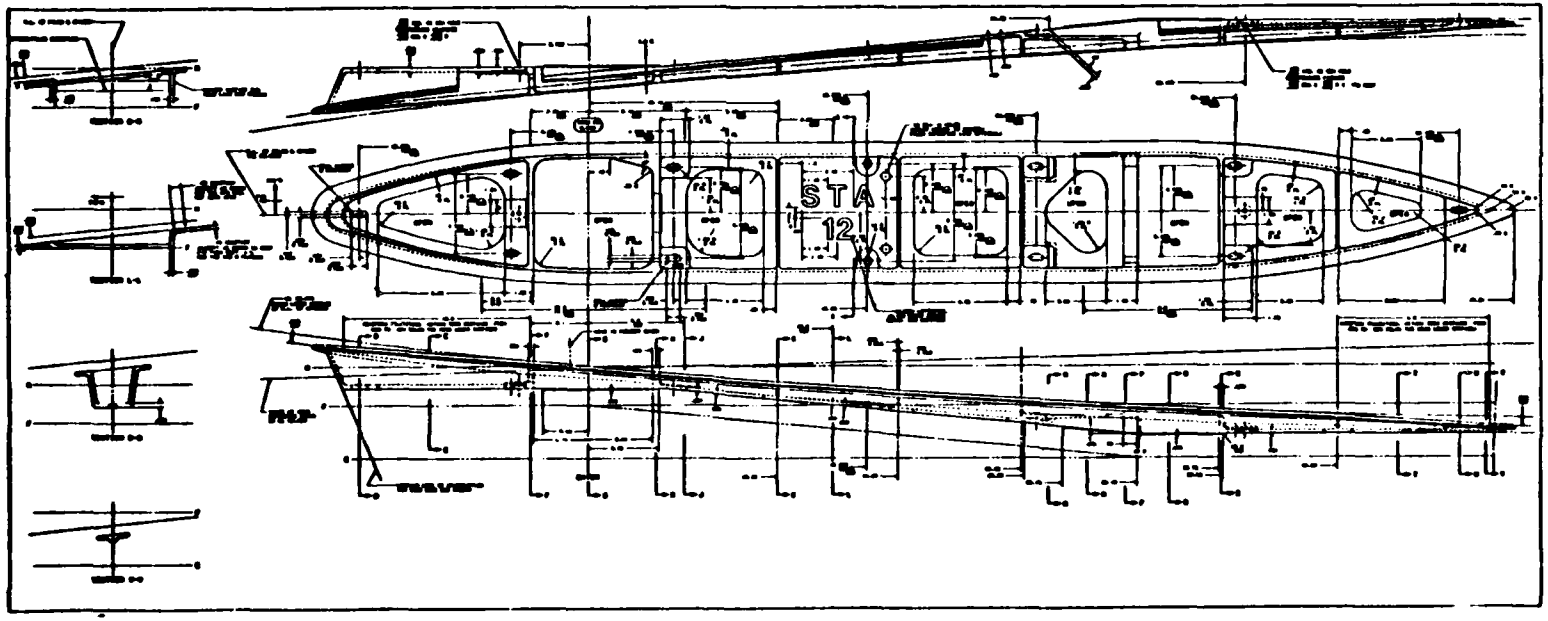
CALAC FORM 6364 C-64

1628196

PYLON COMMONALITY DESIGN



SPACER



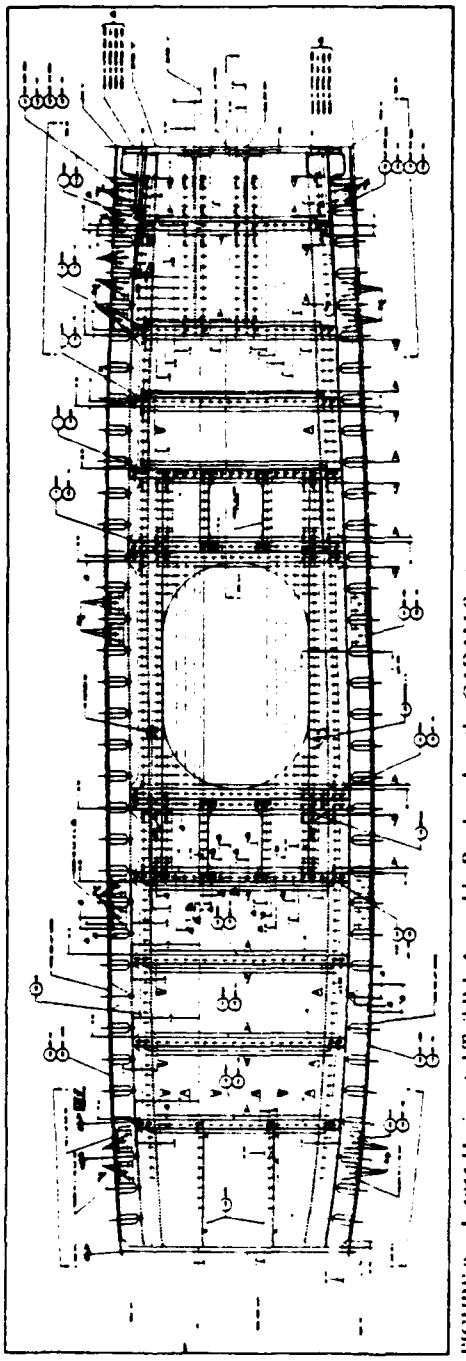
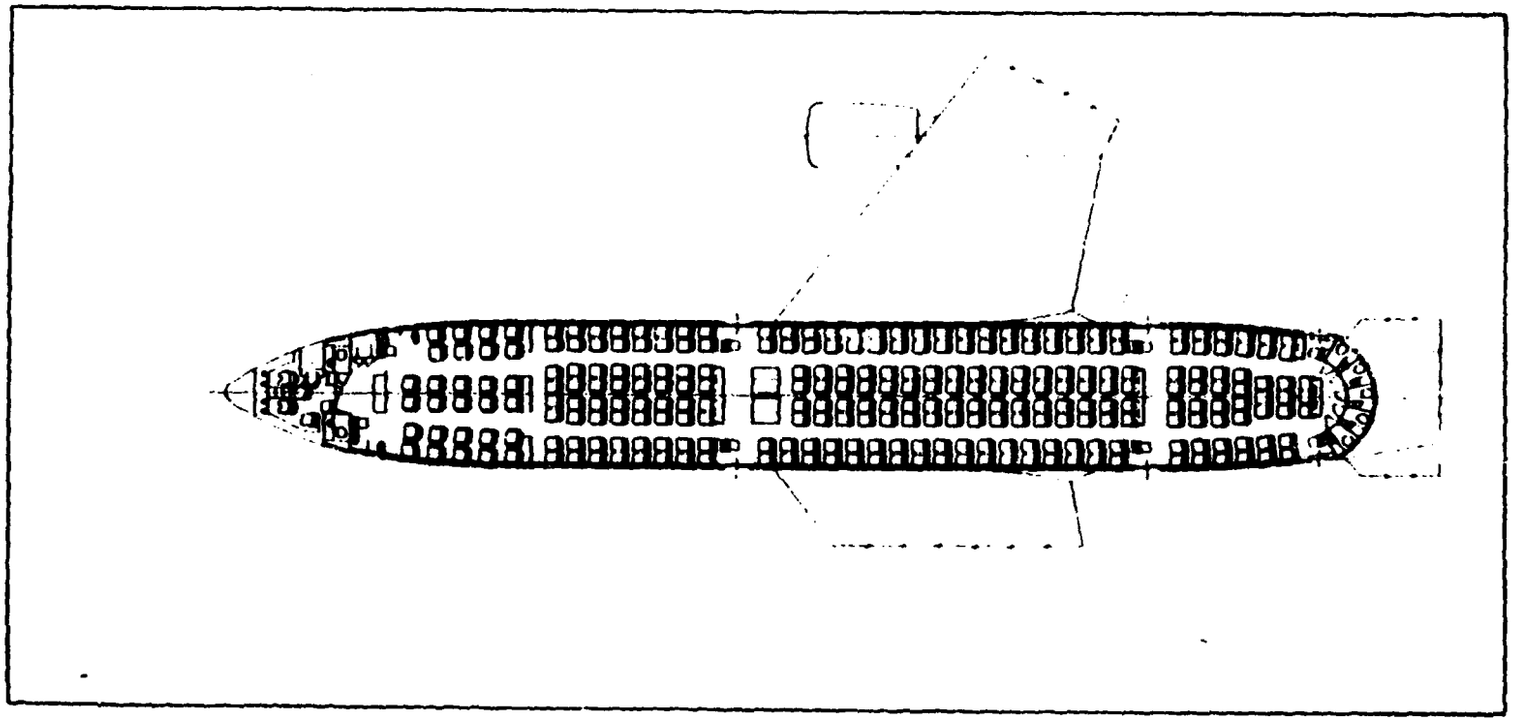
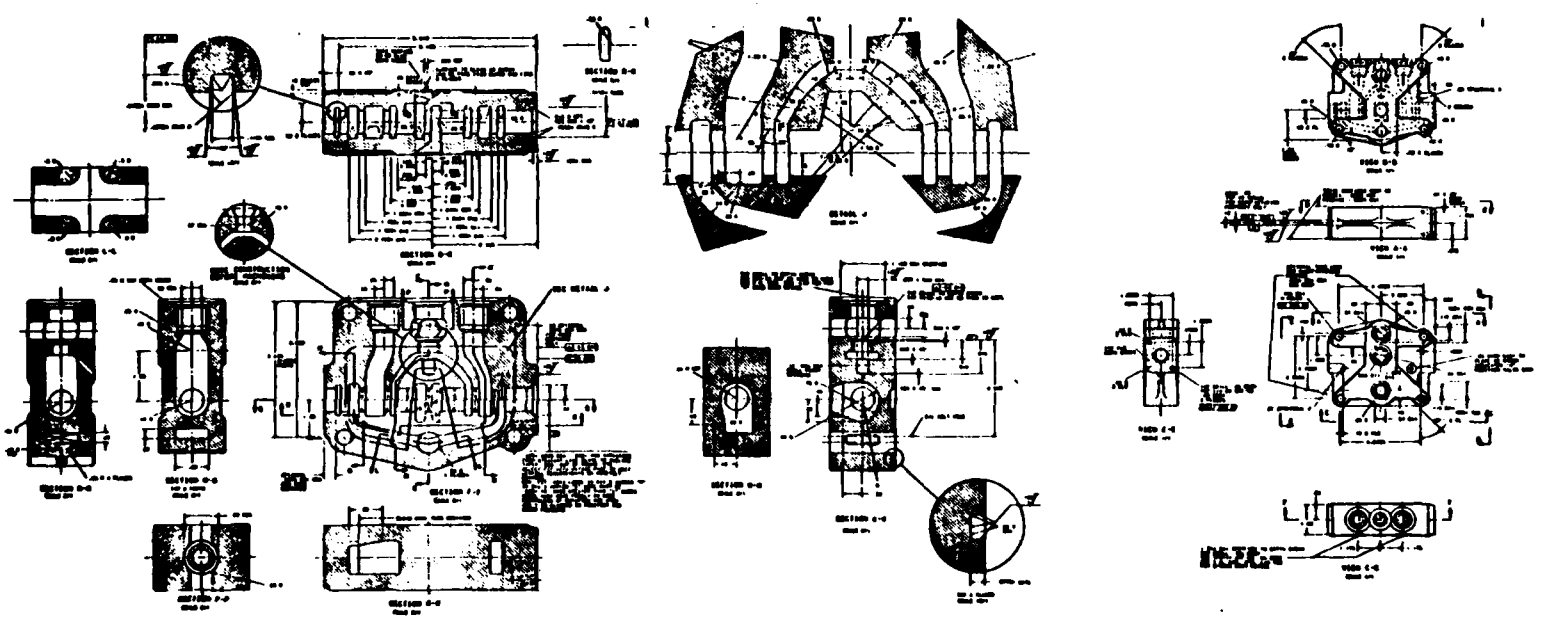


FIGURE 9 L-1011 Horizontal Tail Rib Assembly Produced on the CADAM System

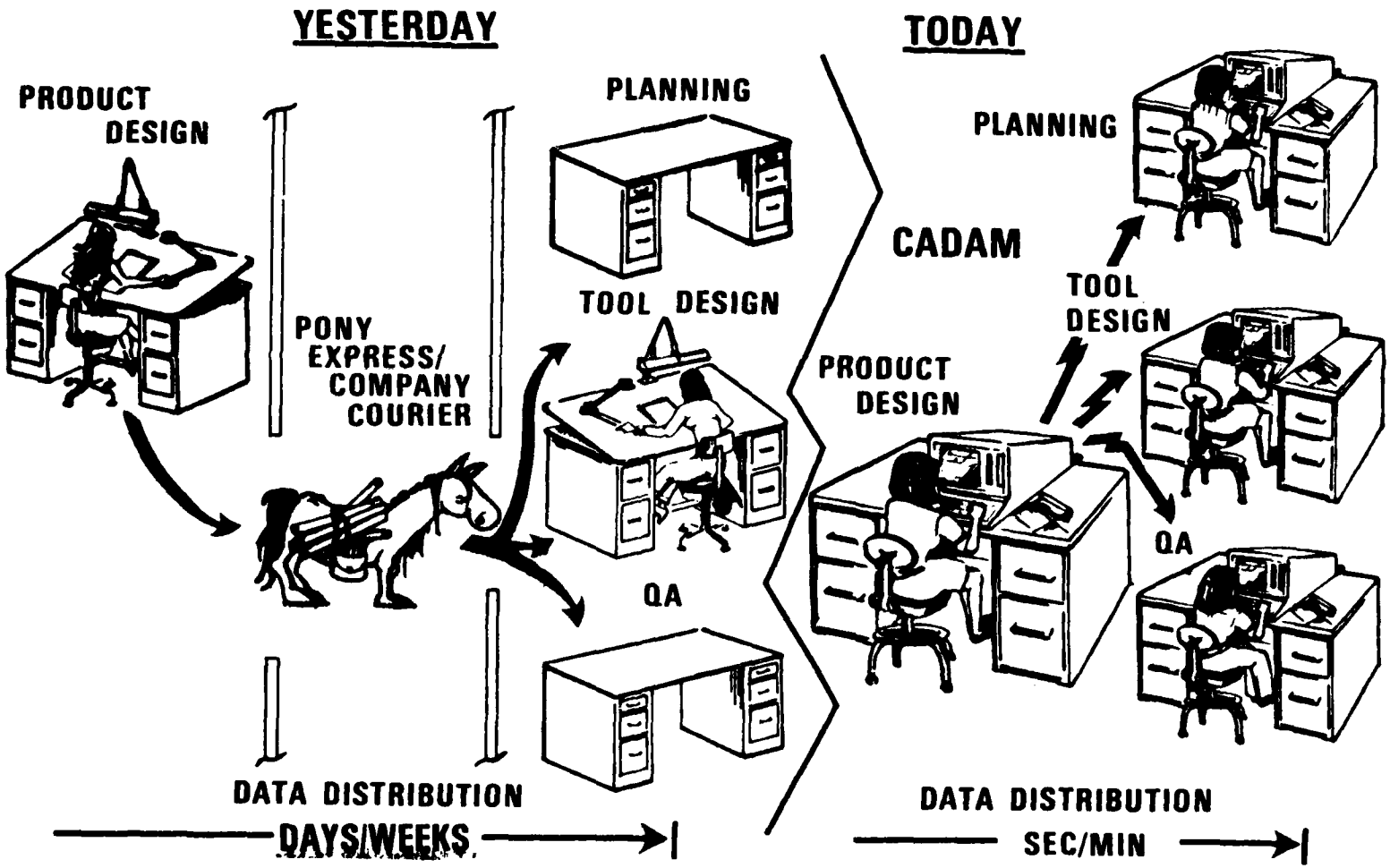
SEATING ARRANGEMENT



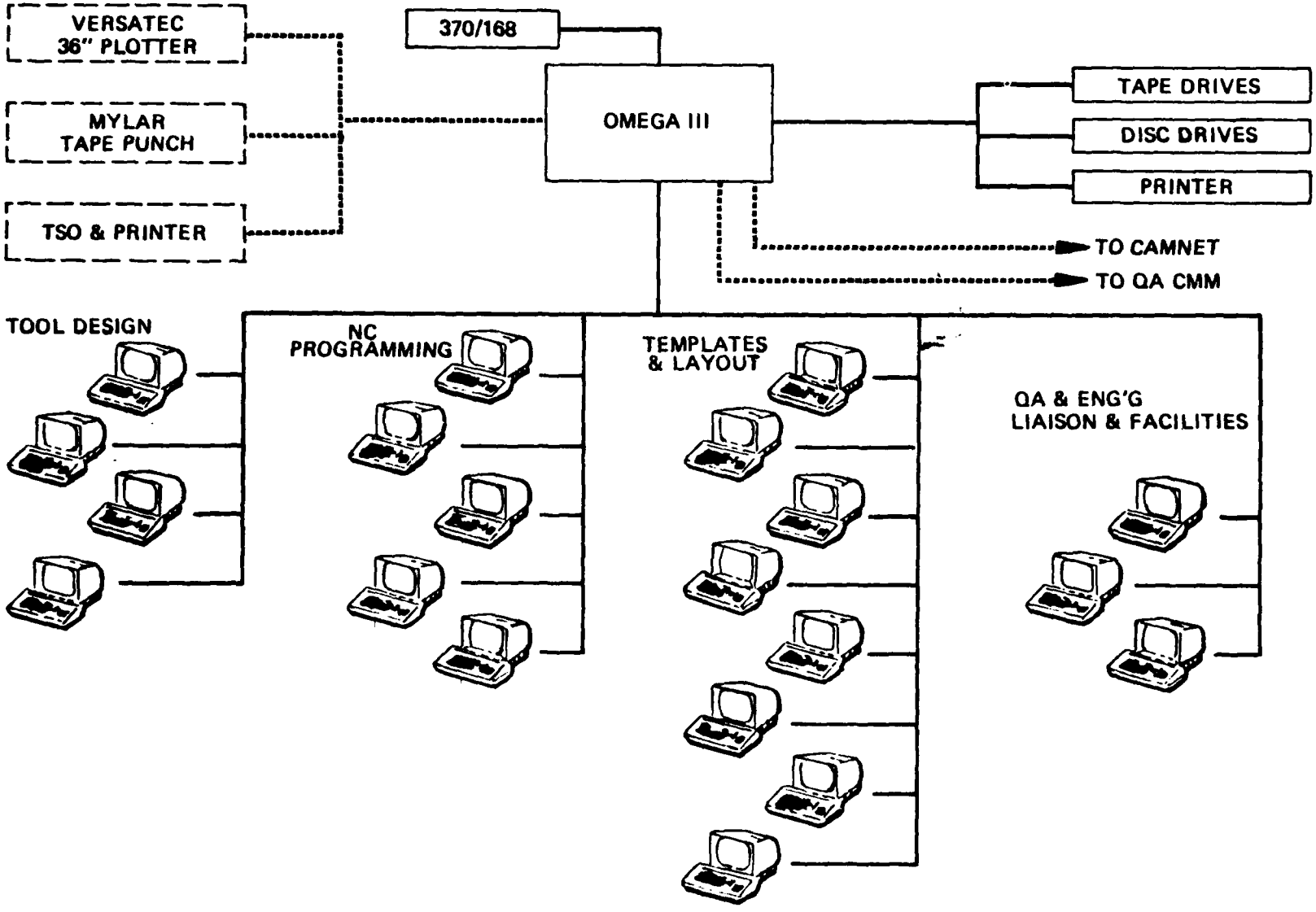
VALVE BODY



APPLICATION OF CADAM IN MANUFACTURING


YESTERDAY
TODAY
PRODUCT DESIGN
PLANNING
PONY EXPRESS/ COMPANY COURIER
TOOL DESIGN
QA
DATA DISTRIBUTION
DAYS/WEEKS
PLANNING
CADAM
TOOL DESIGN
PRODUCT DESIGN
QA
DATA DISTRIBUTION
SEC/MIN

CADAM MANUFACTURING/QA FACILITY

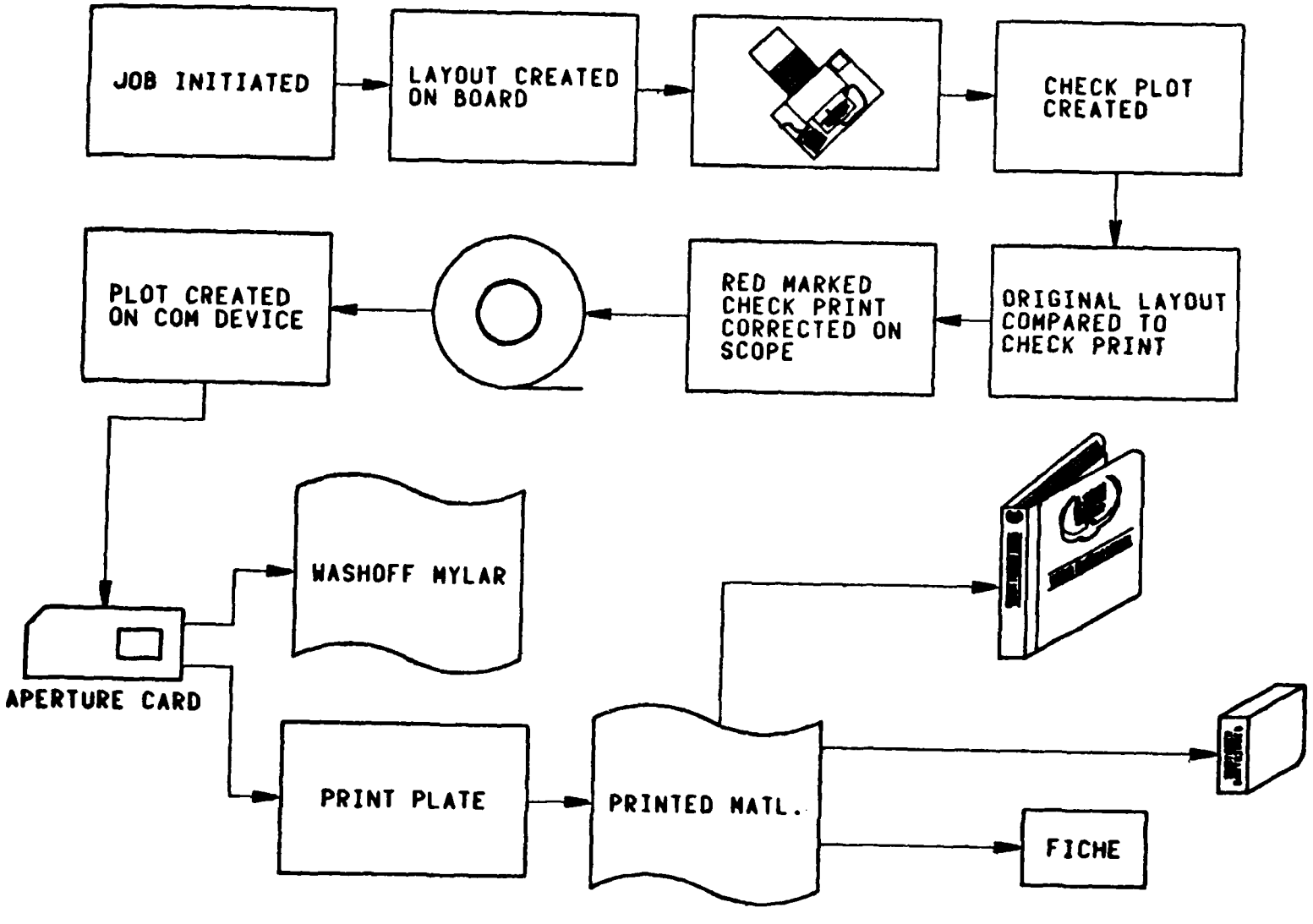


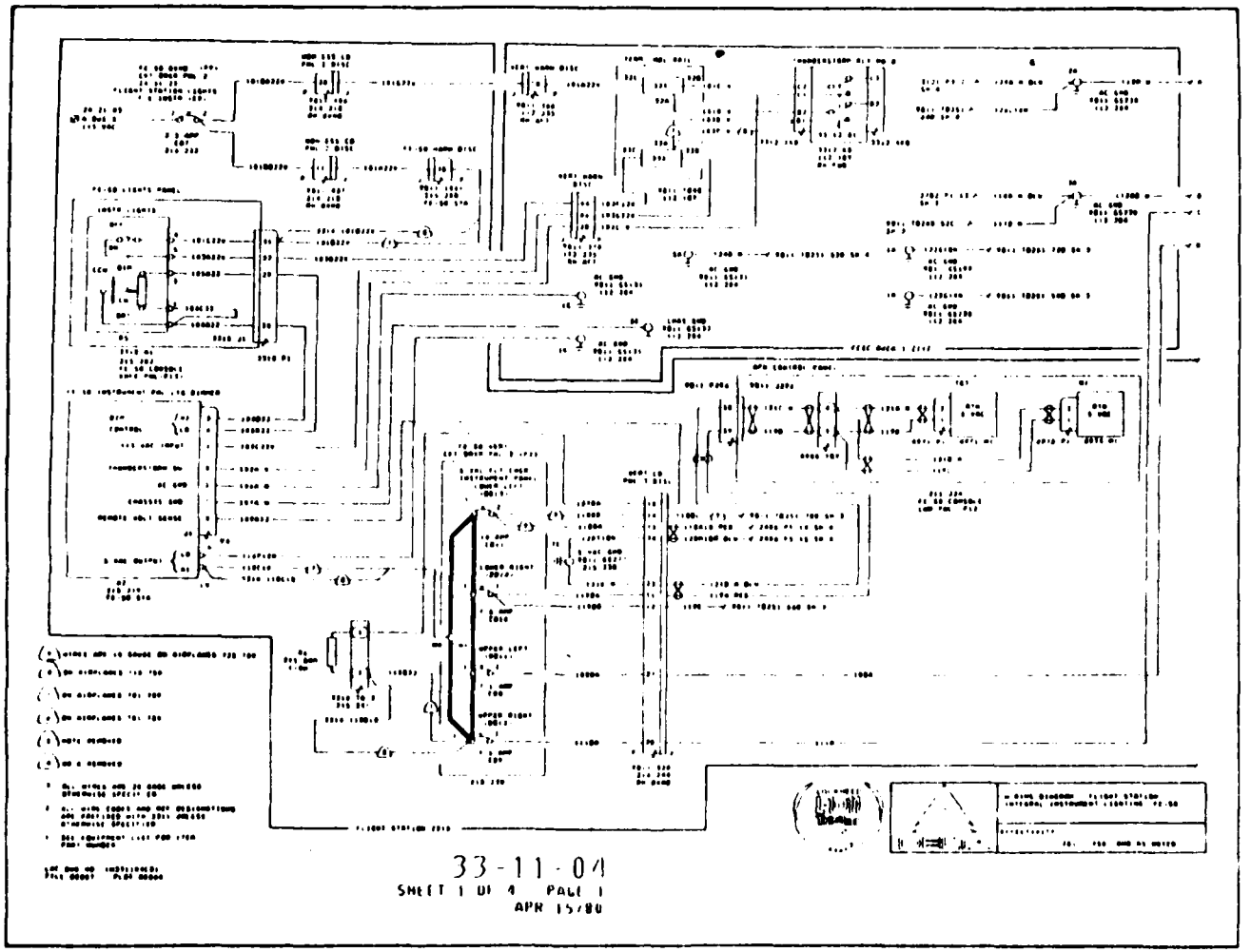
APPLICATION OF CADAM IN PRODUCT SUPPORT

L 1011
WIRING DIAGRAM MANUAL

- WIRING DIAGRAMS DOCUMENT THE ELECTRICAL/ELECTRONIC WIRING IN THE L-1011
- WIRING DIGRAMS ARE USED TO TROUBLE SHOOT INOPERATIVE SYSTEMS
- WIRING DIAGRAMS ARE USED TO DESIGN MODIFICATIONS TO SYSTEMS.

WDM GROUP ACTIVITY FLOW CHART





WIRING DIAGRAM
FIGURE 1.102

VIEW PV SCL 1.000 WDO 1.000,.0

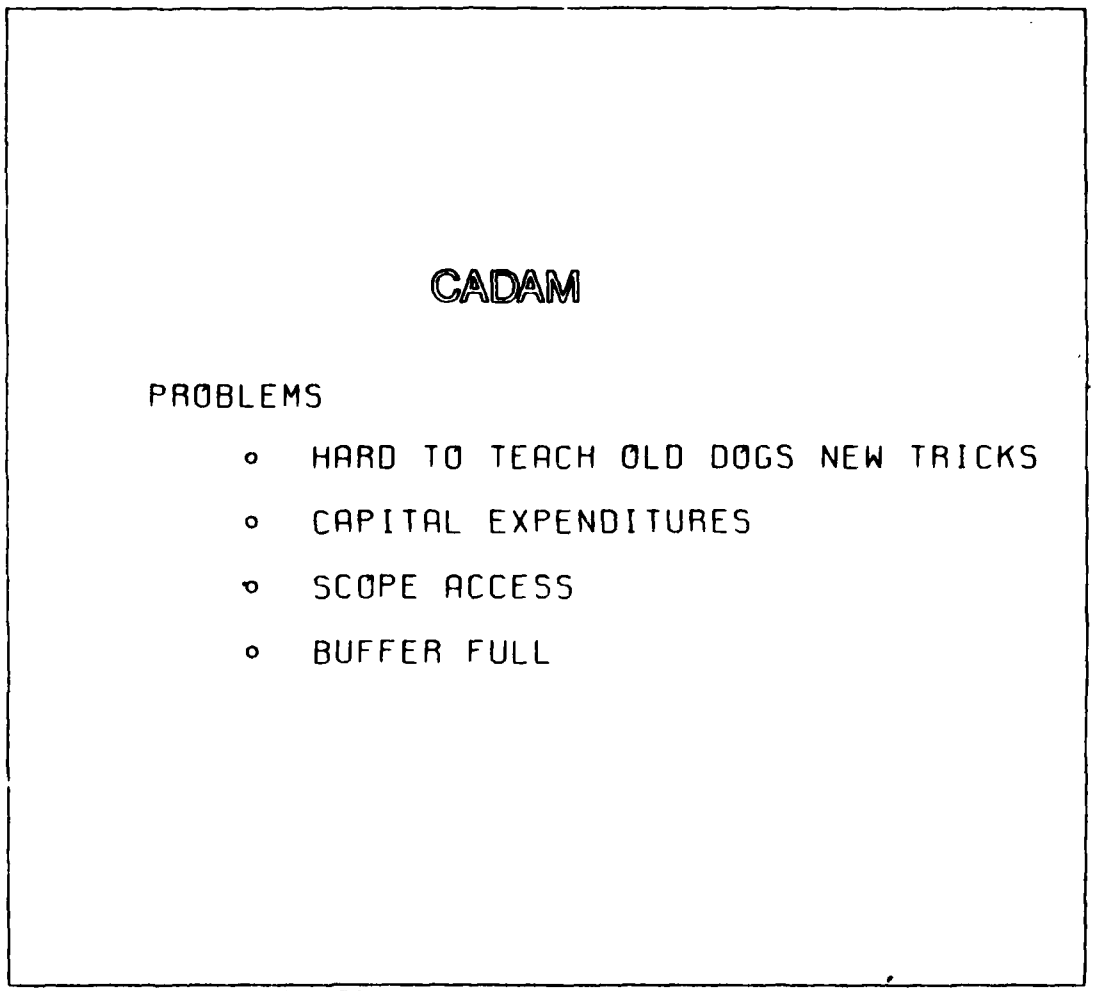
CADAM

ADVANTAGES

- REDUCED COSTS
- REDUCED MAN-HOURS
- SHORTER TIME SPAN
- LESS ERRORS
- GREATER ACCURACY
- CAPABILITY TO PERFORM MORE DESIGN ITERATIONS
- COMMON DATA BASE
- EASIER AND FASTER REDESIGN
- ONLY SOLUTION TO SOME JOBS

/ PLOT1 / PLOT3 / FILM / WINDOW / NEW FRAME / OLD FRAME / ELECTRO /

VIEW PV SCL 1.000 WDO 1.000,.0

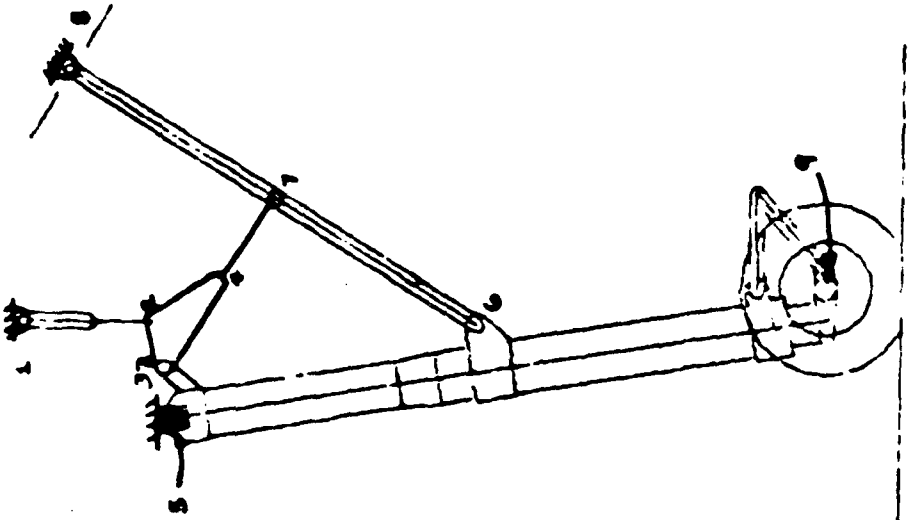


/ PLOT1 / PLOT3 / FILM / WINDOW / NEW FRAME / OLD FRAME / ELECTRO /

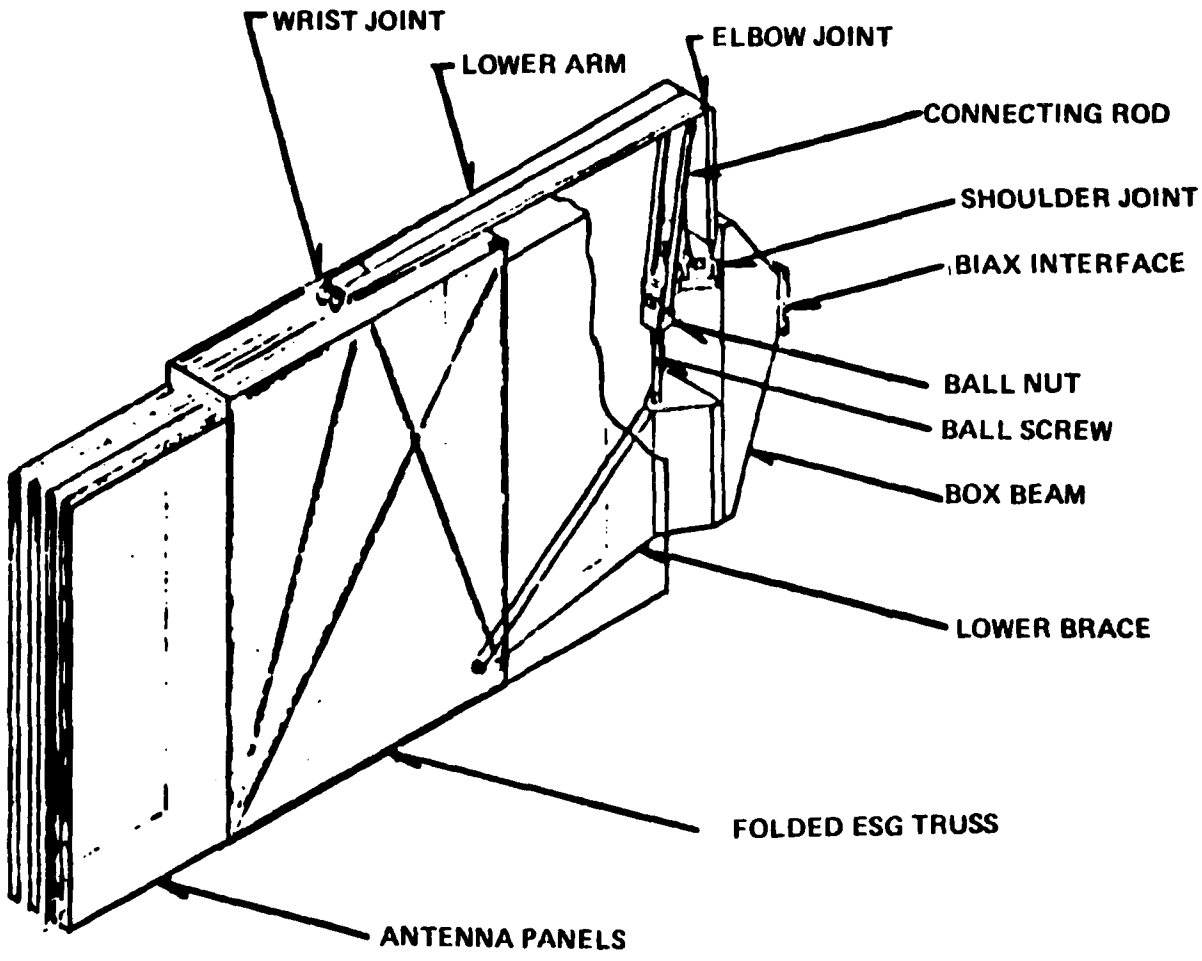
MECHANISMS

APPLICATIONS

- AIRCRAFT
  - LANDING GEARS
  - CONTROL LINKAGES
  - CONTROL VALVES
  - DOOR LATCHING MECHANISMS
  - FLAP TRACKS
  - AIR STAIRS
- SPACECRAFT
  - SOLAR PANELS
  - ANTENNAS
  - SPACE SHUTTLE ARM

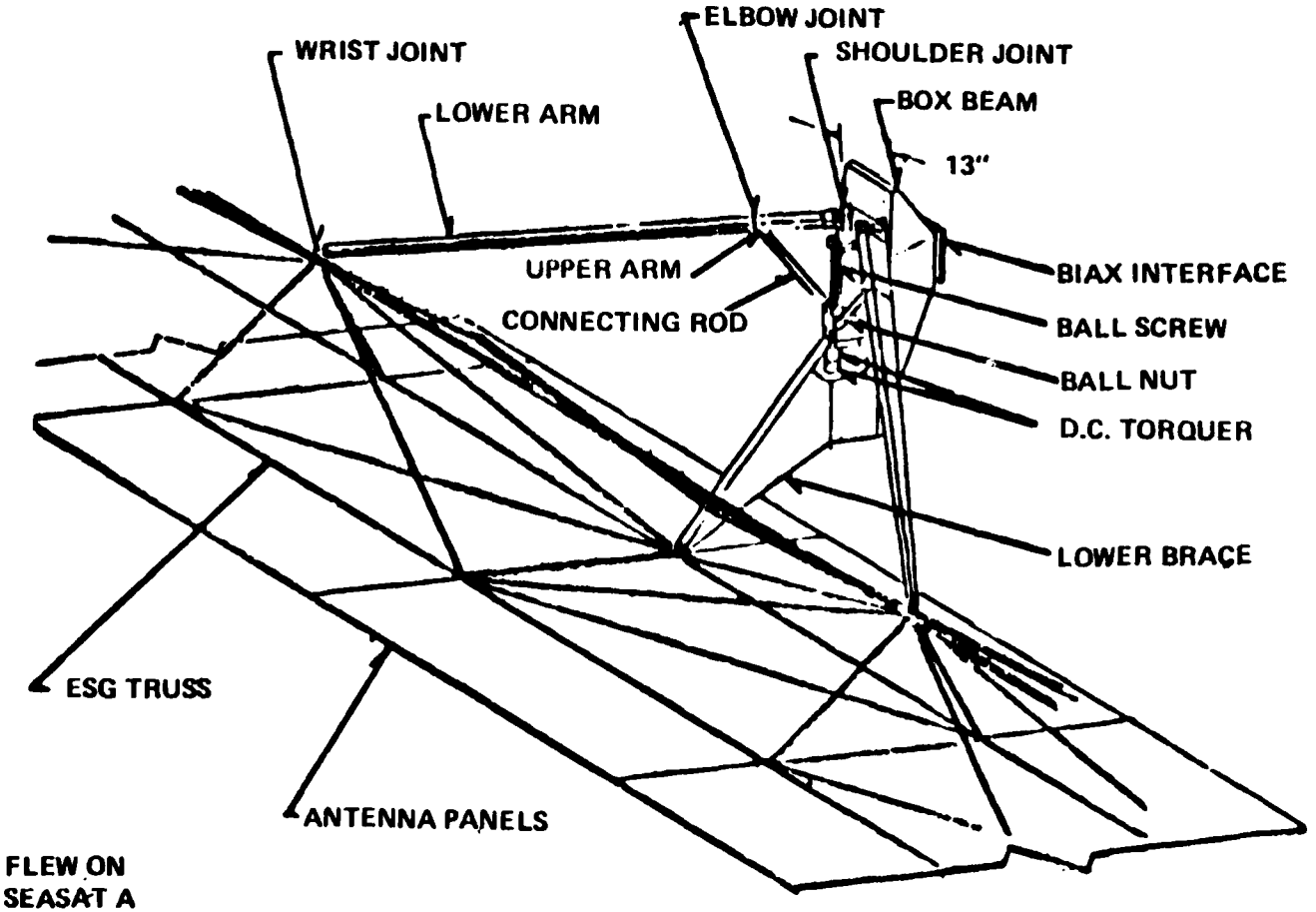


STOWED EXTENDIBLE SUPPORT STRUCTURE



DEPLOYED EXTENDIBLE SUPPORT STRUCTURE

SYNTHETIC APATURE RADAR (SAR)



FLEW ON
SEASAT A

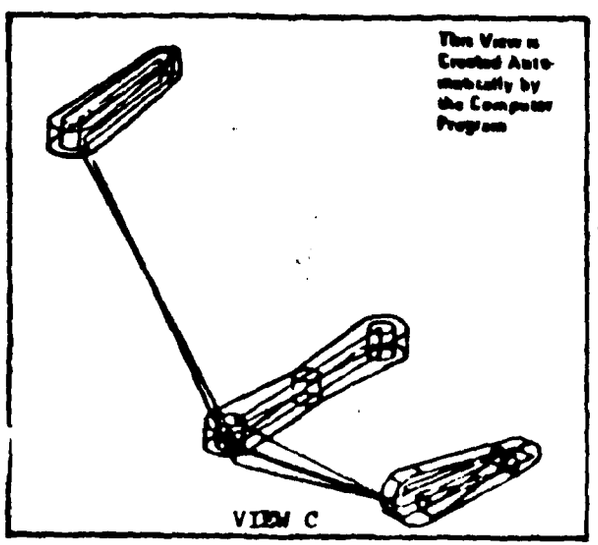
MECHANISM DESIGN

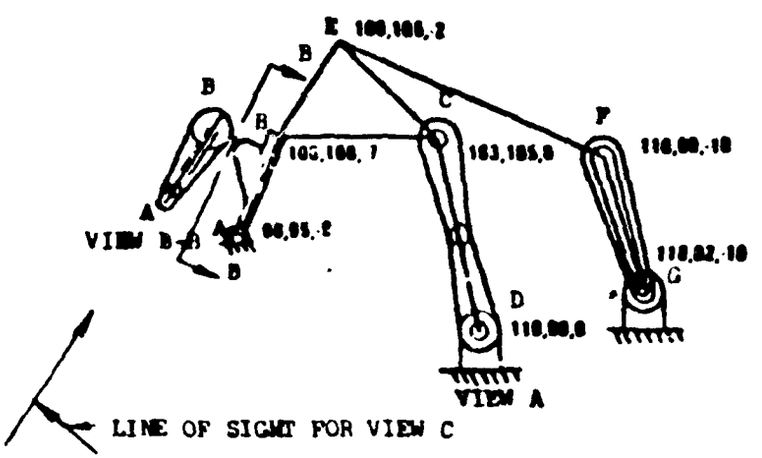
- POSITION - VELOCITY - ACCELERATION ANALYSES
- STRUCTURAL LOADS AND DEFLECTION ANALYSIS
- MECHANICAL ADVANTAGE
- CLEARANCE PROBLEMS

PRESENT CAPABILITIES

- INTEGRATED IN CADAM
- 3-D MOTION SIMULATION
- 16 BASIC UNITS
- LARGE MODEL CAPABILITY
- TABULAR AND GRAPHICAL OUTPUT

THREE-DIMENSIONAL MECHANISM

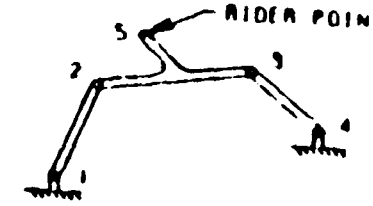




MOTION SIMULATION

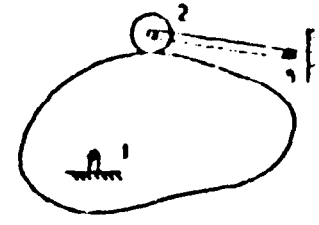
LINK

FOUR BAR

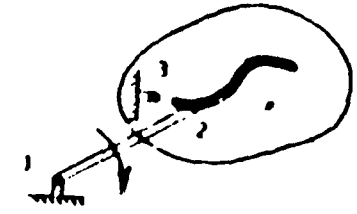


FOURBAR WITH RIDER POINT

FOURBAR DRIVEN BY LINK
THROUGH RIDER POINT

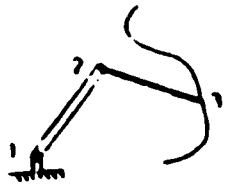


CAM

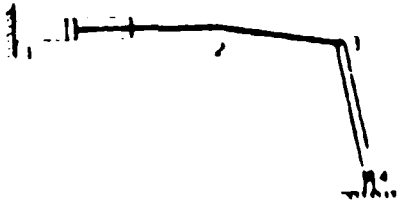


SLOT

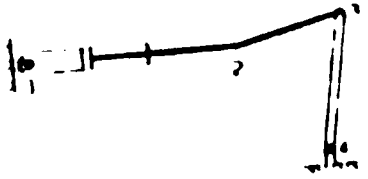
MOTION SIMULATION



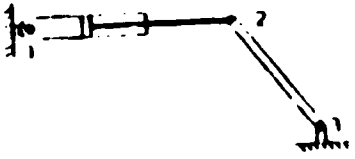
TRACK



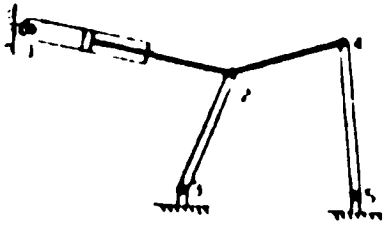
FIXED END ACTUATOR
DRIVING LINK



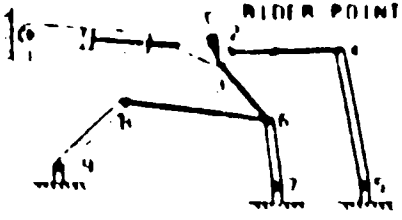
ACTUATOR DRIVING LINK
THROUGH INTERMEDIATE LINK



ACTUATOR DRIVING LINK

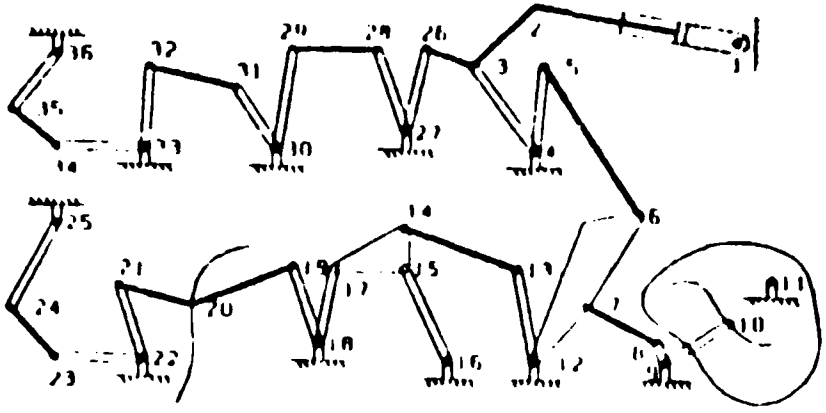


ACTUATOR DRIVING A
FOURBAR UNIT



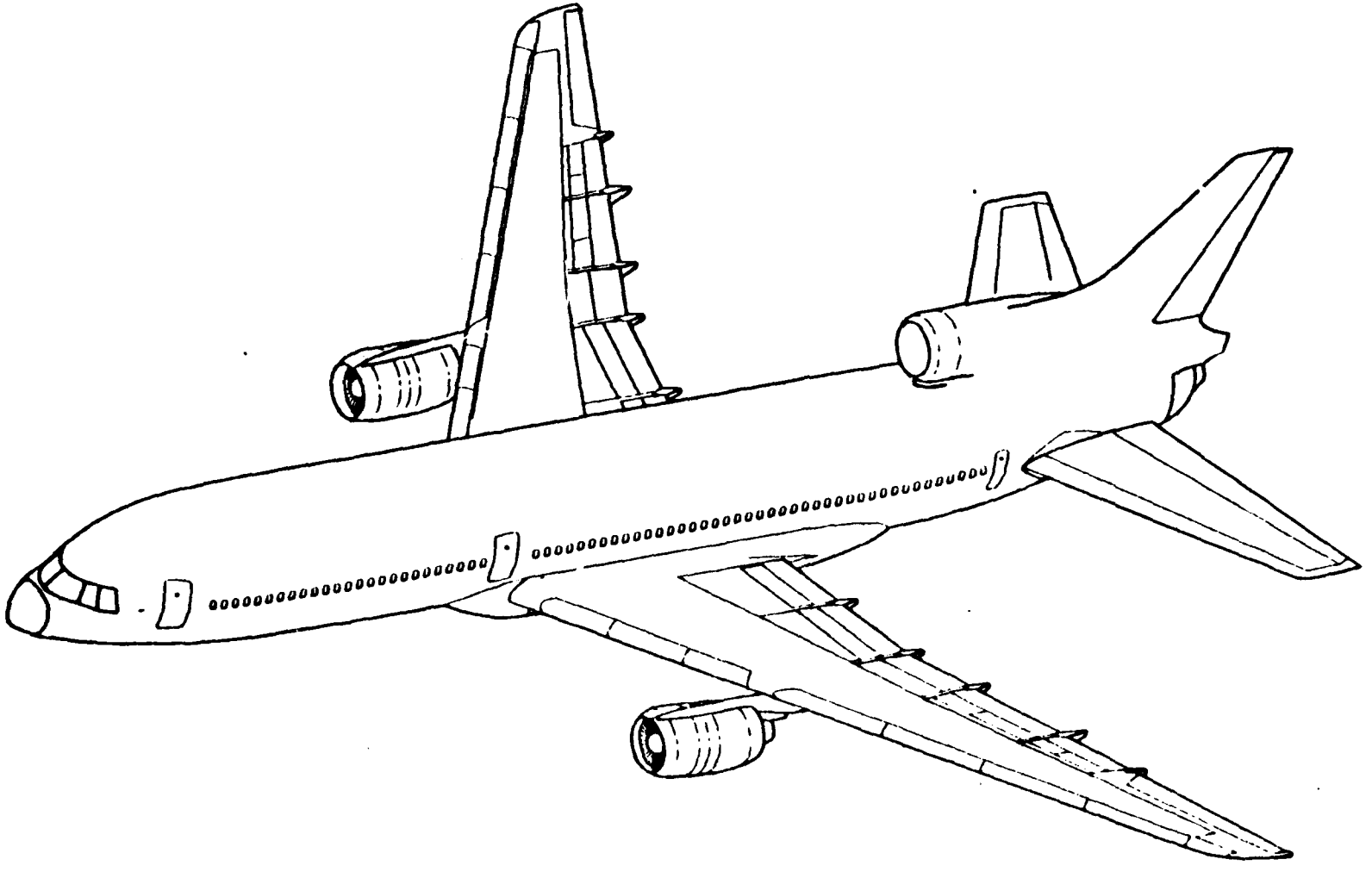
ACTUATOR DRIVING UNIT
THROUGH RIDER POINT

MOTION SIMULATION



LARGE MODELS

SURFACES



SURFACES

AIRSWEPT SURFACE DEFINITION

LOFTING

SURFACE LOFTING

SURFACE DESIGN

LOFTING APPLICATION

- INITIATED IN PRELIMINARY DESIGN
- EVOLVES AND MATURES WITH PROJECT
- RESULTS IN SURFACE SHAPE DEFINITION
- USED BY: PRELIMINARY DESIGN
  PRODUCTION
  TOOLING AND FABRICATION

LOFTING PROBLEM

DEFINE A SMOOTH SURFACE WITH LUMPS

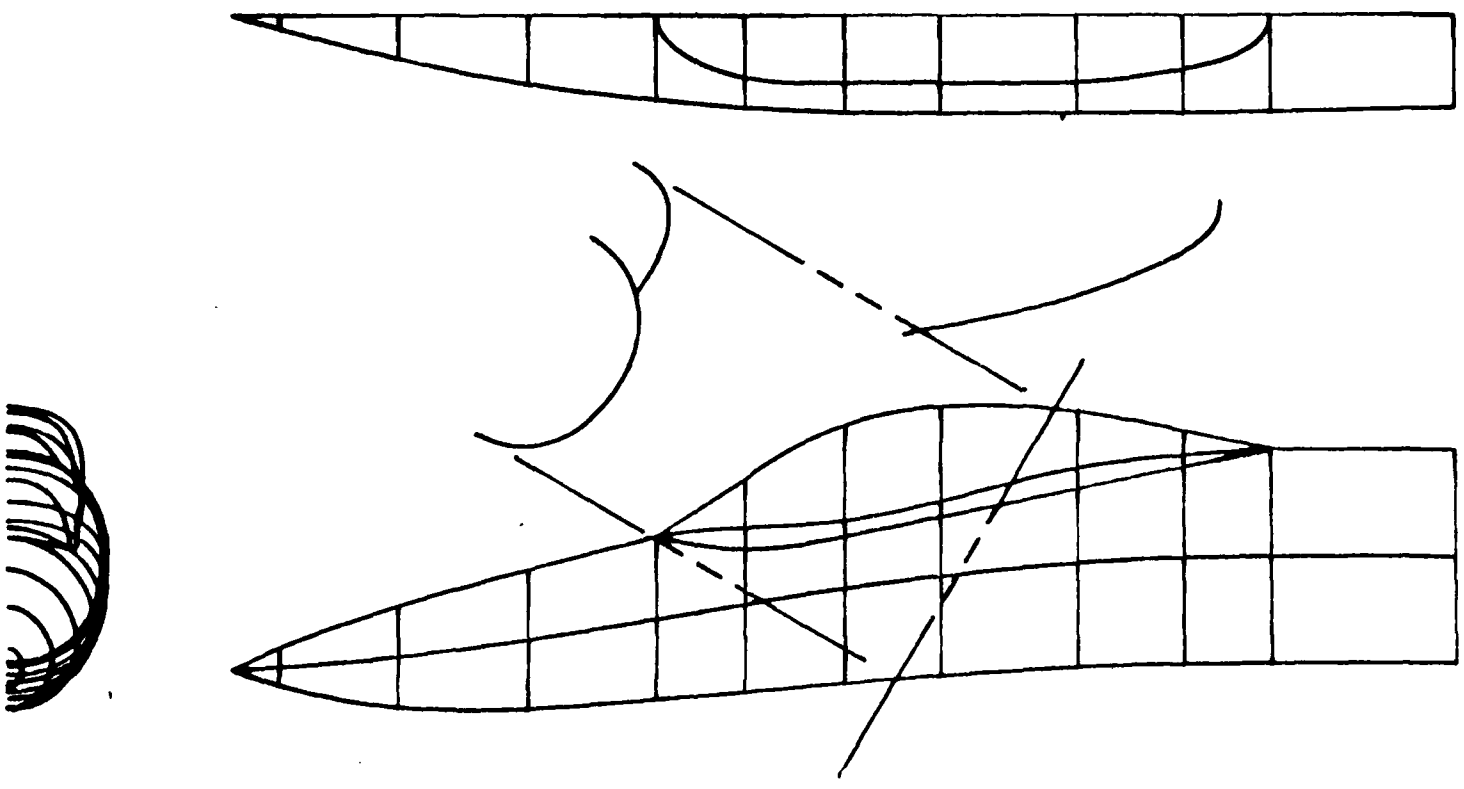
CONSTRAINTS:

- ENCLOSE: STRUCTURE, CREW, AVIONICS, ETC.
- MEET AERODYNAMIC REQUIREMENTS
  - AREA PROGRESSION
  - SHAPE
  - SMOOTHNESS
  - FAIRNESS

LOFTING METHODS

- MANUAL - HAYLOFT
- COMPUTER AIDED
  - MESH OF POINTS
  - PATCHES
  - NET OF CURVES

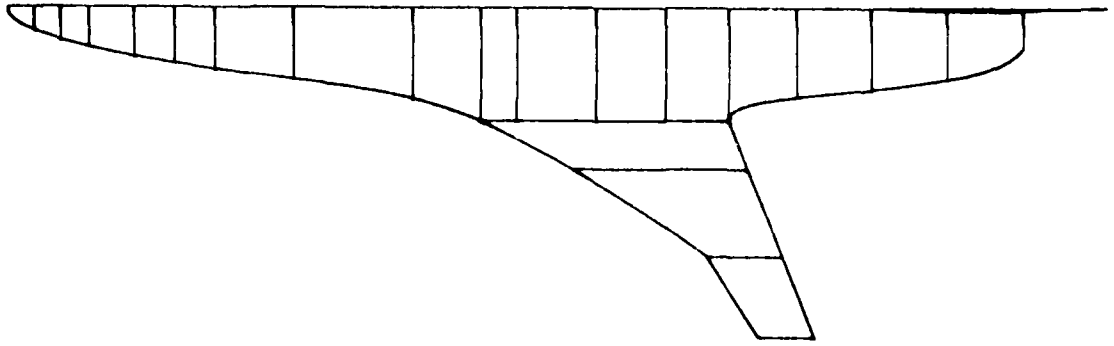
DESIGN CURVES - SURFACE RESULTS

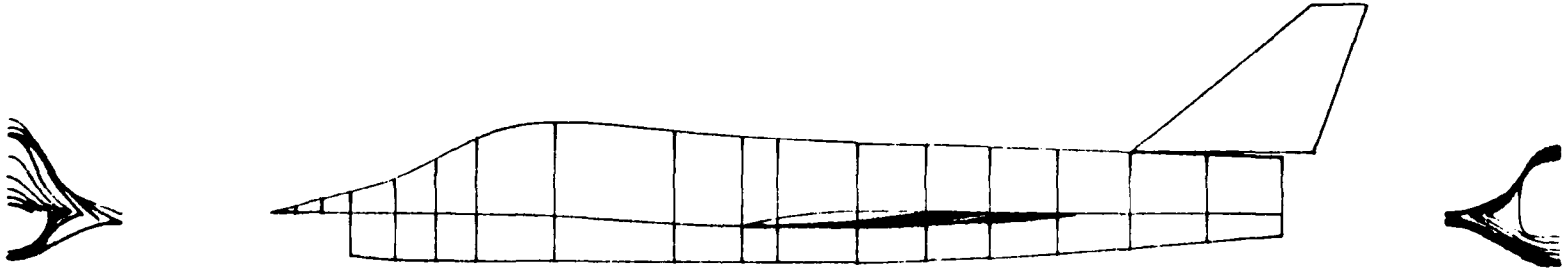


TIME COMPARISON

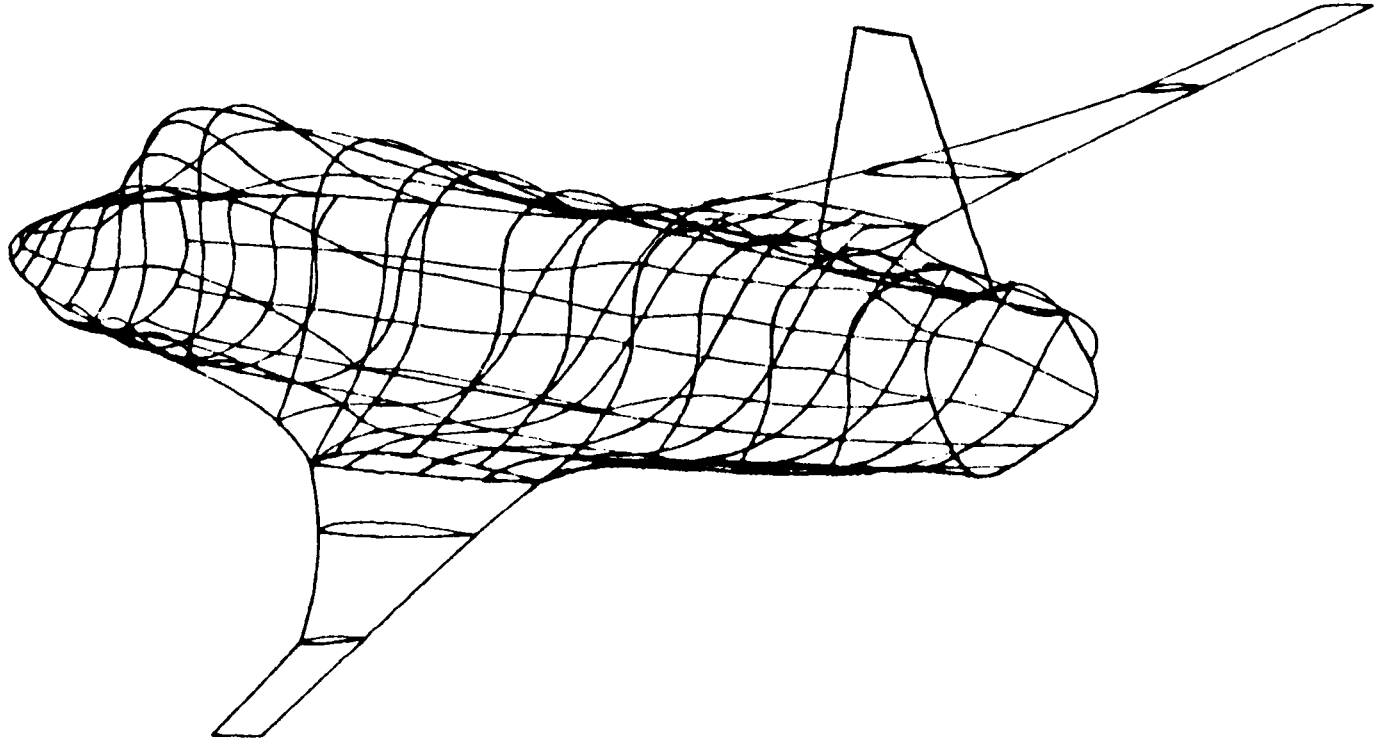
OLD SYSTEM	TASK	NEW SYSTEM
1000 HRS. EST. 3 MONTHS SPAN	RADOME	20 HRS. ACTUAL 1 WEEK SPAN
900 HRS. EST. 3 MONTHS SPAN	WING FILLET	6 HRS. ACTUAL 1 DAY SPAN
80 HRS. EST. 1 WEEK SPAN	HORIZONTAL TAIL	2 HRS. PD ACTUAL 0 SPAN
500 HRS. EST. 2 MONTH SPAN	HORIZONTAL TAIL TIP	8 HRS. ACTUAL 2 DAYS SPAN

DESIGN WITH 3-VIEW



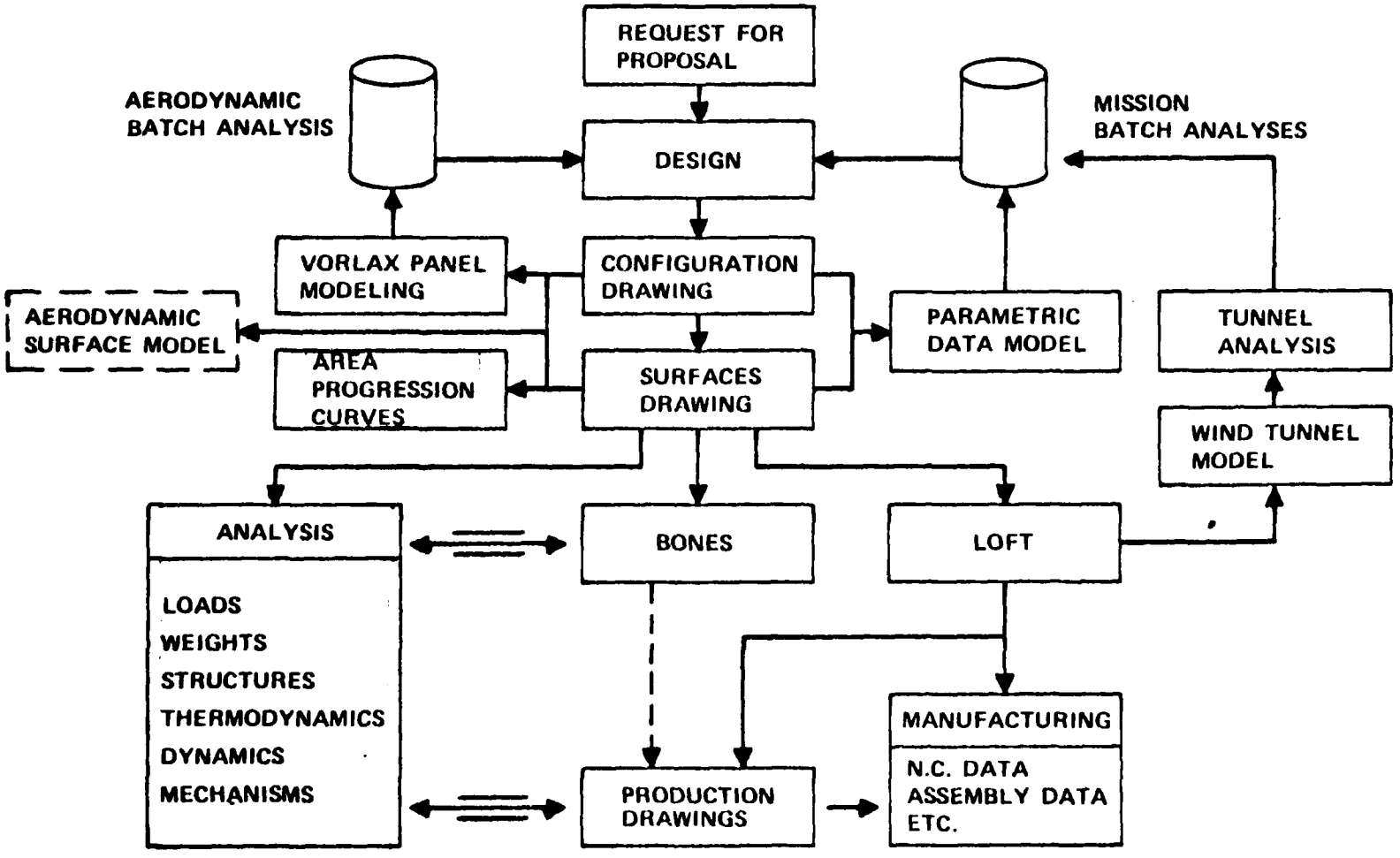


40 HOURS FROM ROUGH LAYOUT



ANALYSIS MODELING

DESIGN PROCESS



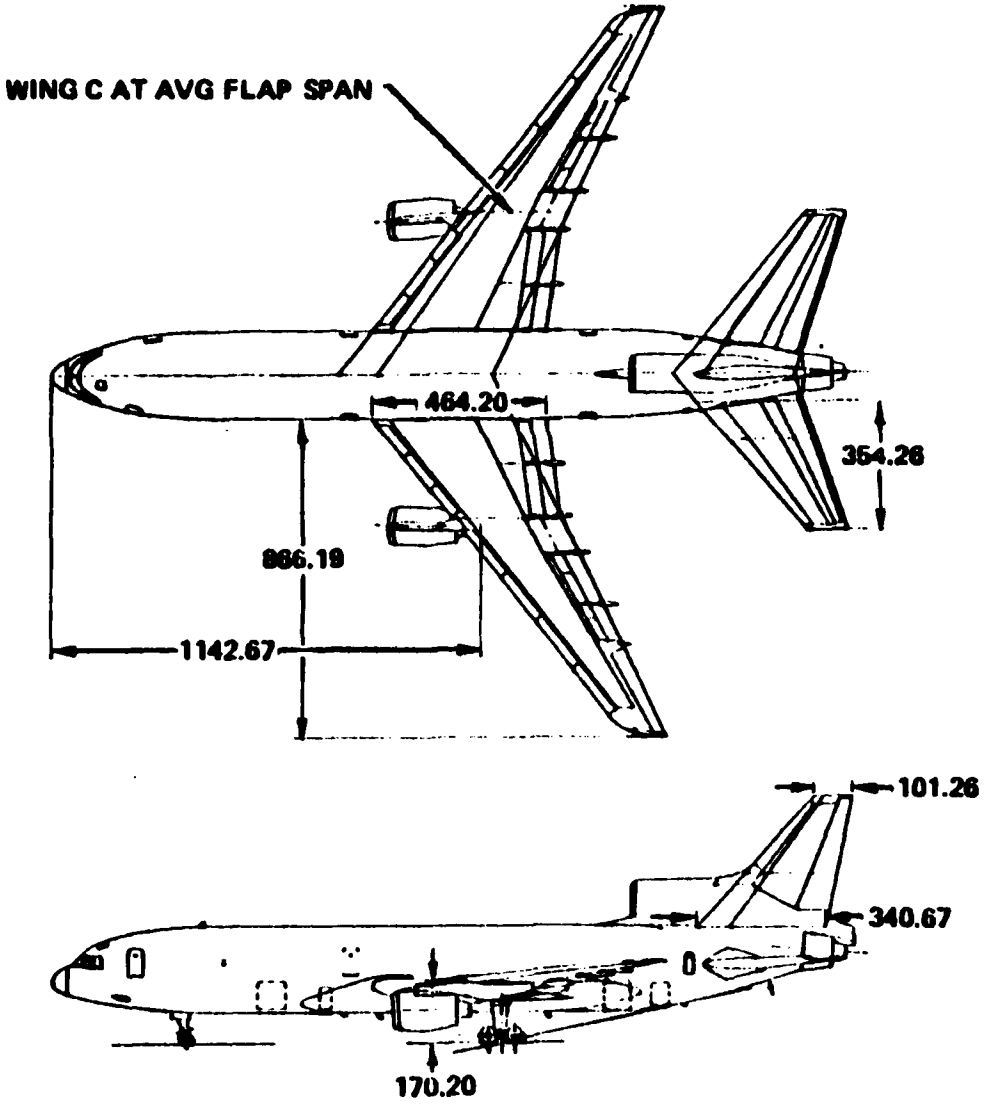
INTRODUCTION

- EXISTING DATA BASE
- EXTRACTION OF DATA
- TECHNIQUES
  - REAL TIME
  - BATCH

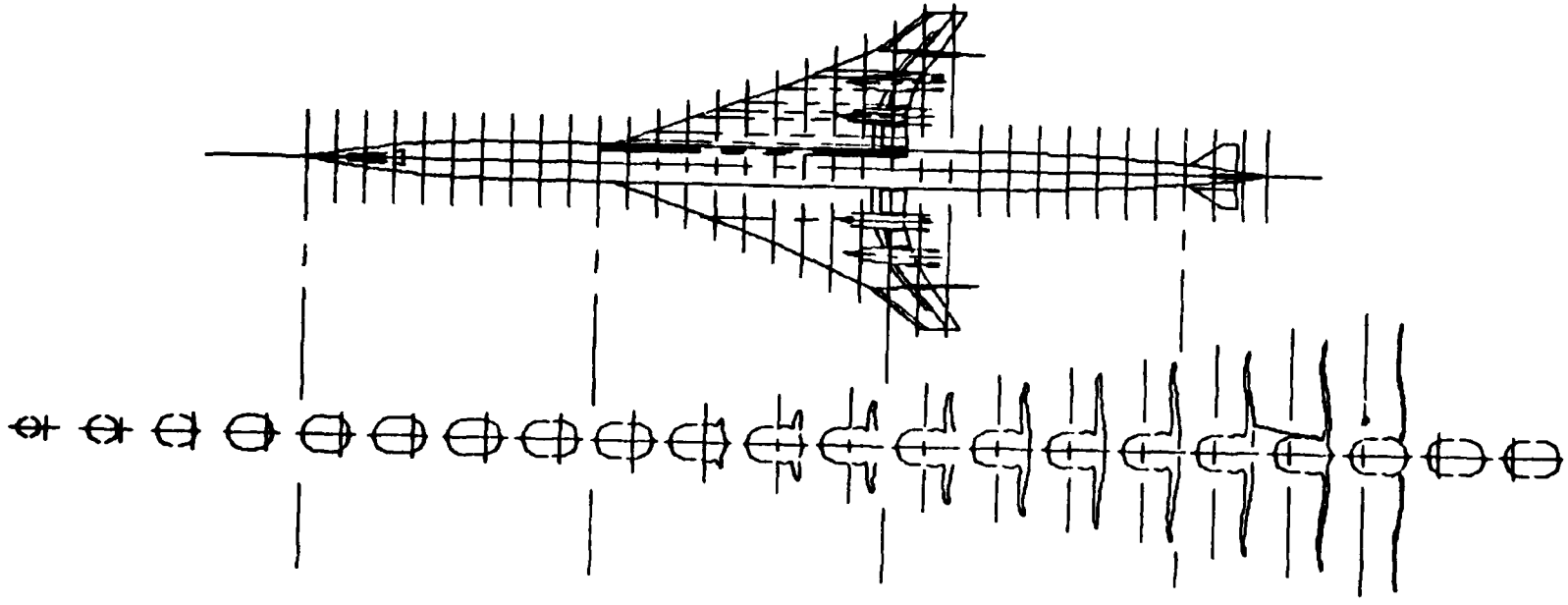
TYPE OF ANALYSIS DATA

- PARAMETRIC (SINGLE VALUE)
  - AREAS, LENGTHS, ETC.
- GRIDS
  - 3-D POINTS, LINE ELEMENTS, PANELS
- SURFACES
  - CURVES WITH SPATIAL RELATIONSHIPS, ETC.

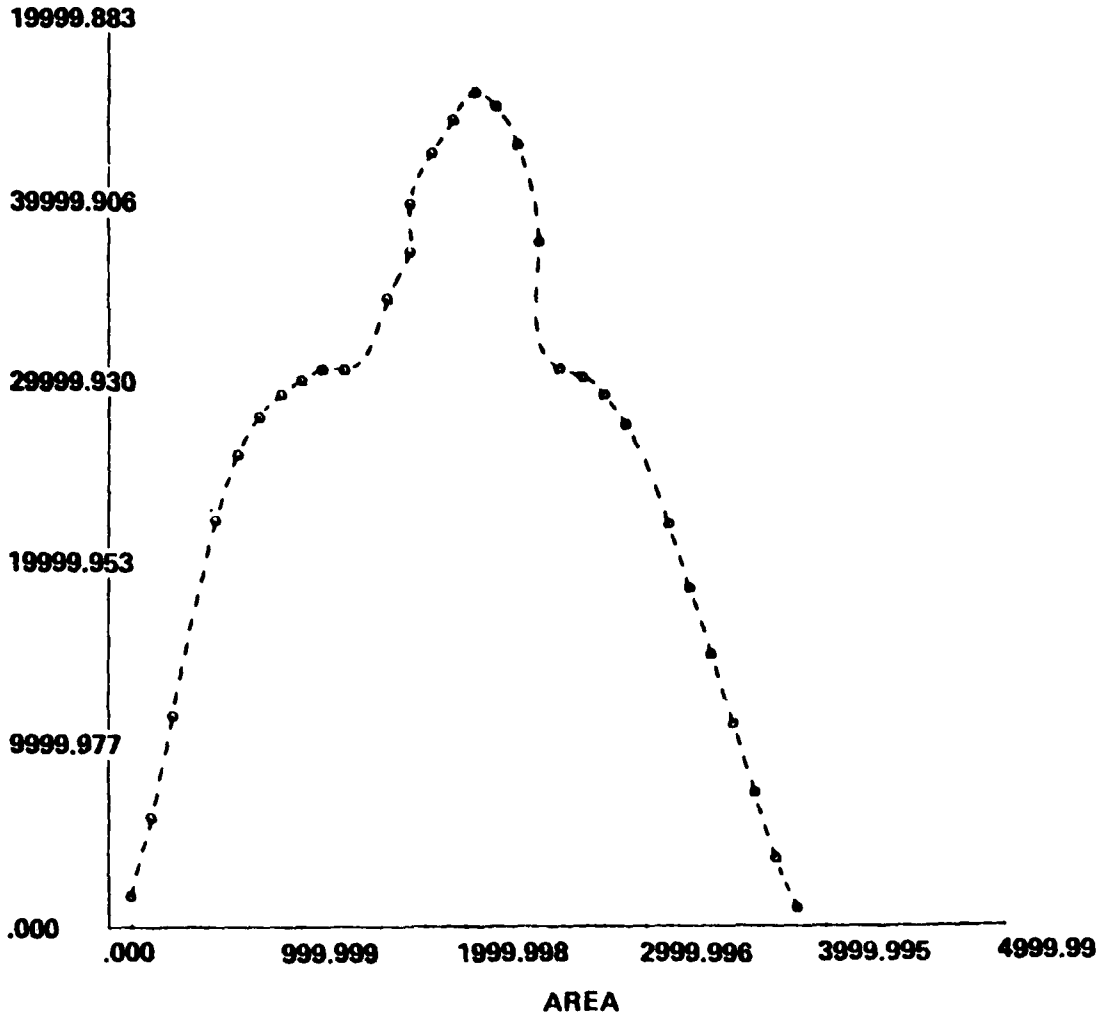
MISSION ANALYSIS



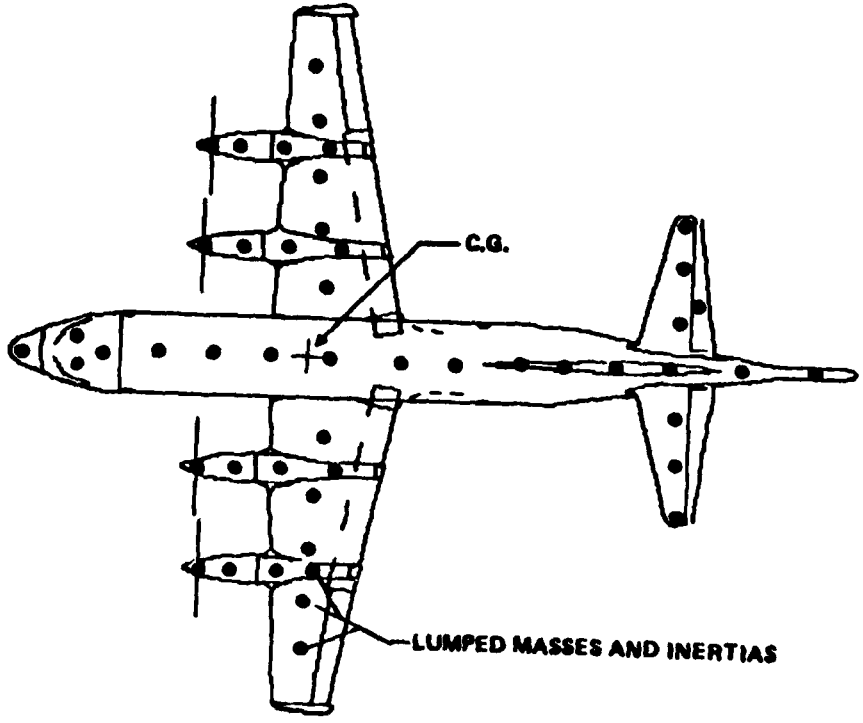
AREA PROGRESSION



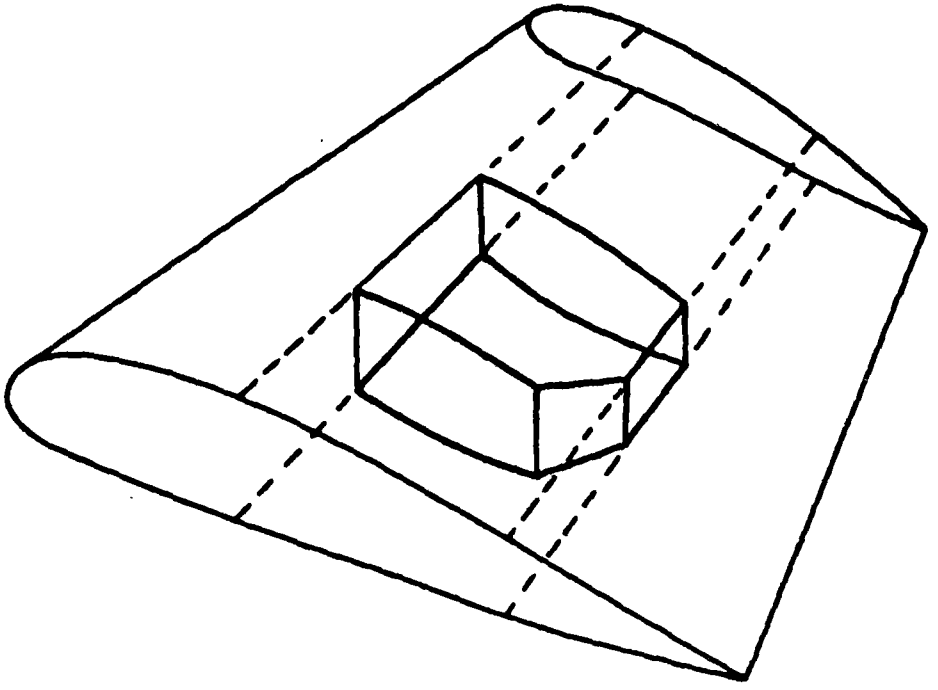
AREA PROGRESSION OUTPUT CURVE



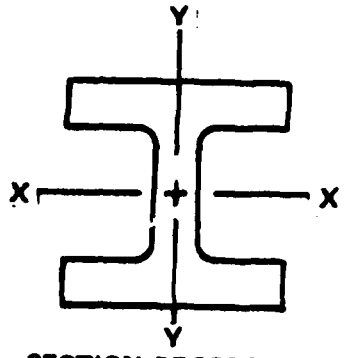
WEIGHT AND BALANCE



FUEL TANK STUDIES

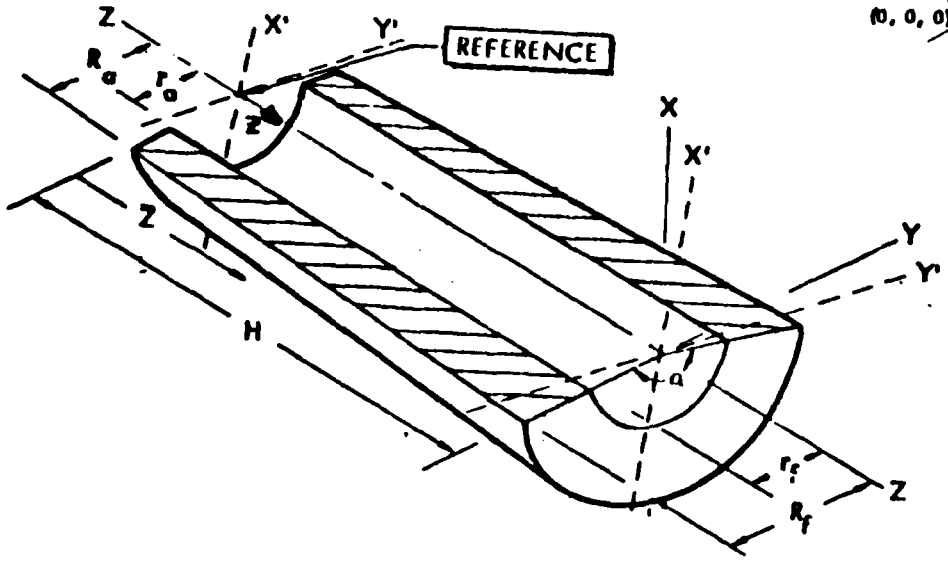


DETAIL MASS AND SECTION PROPERTIES



SECTION PROPERTIES

SURFACE OF REVOLUTION



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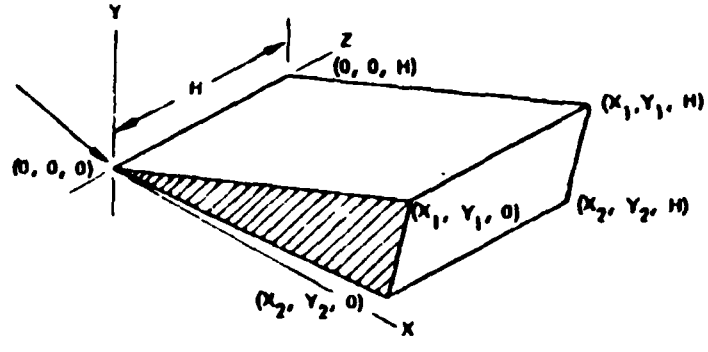
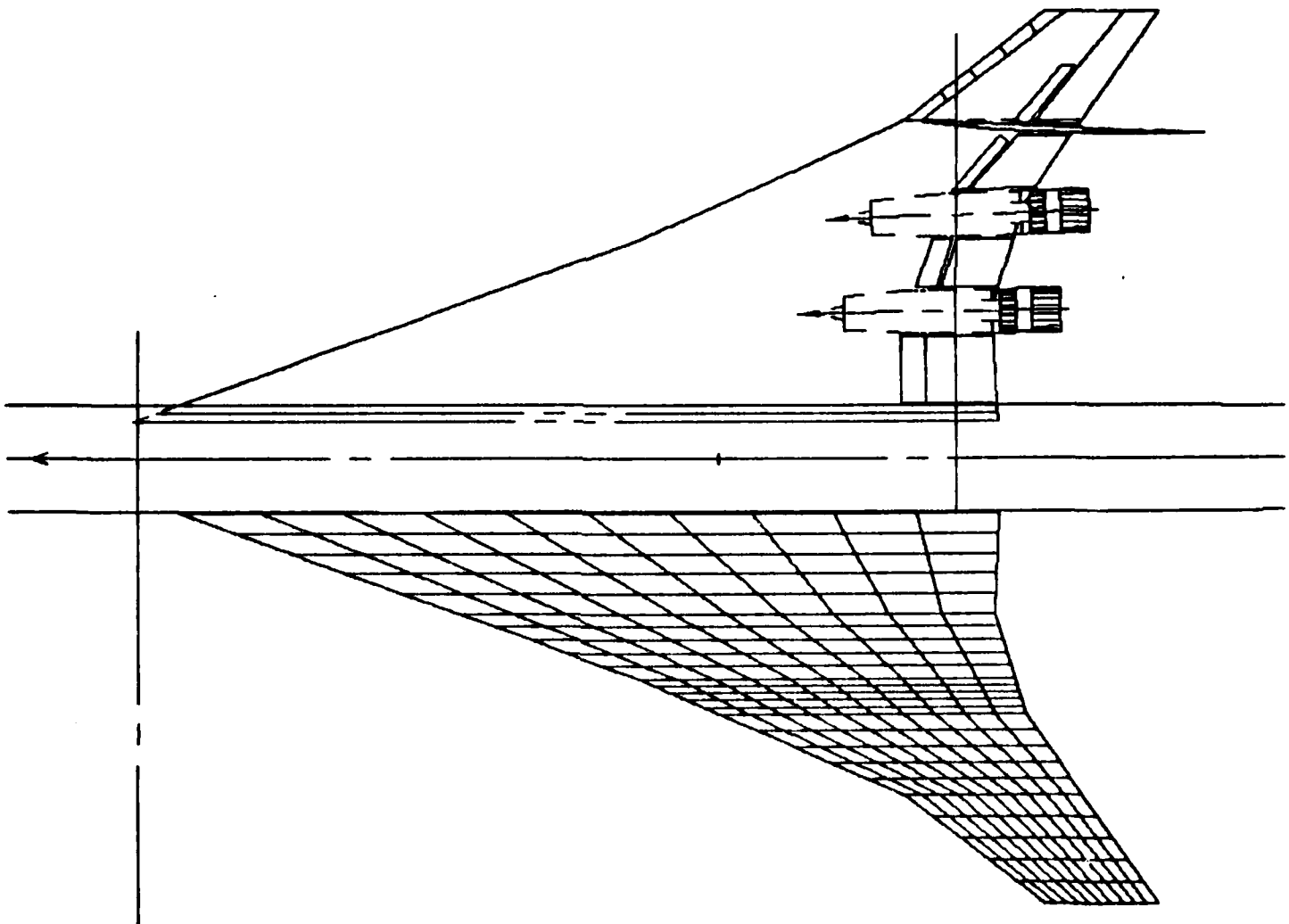
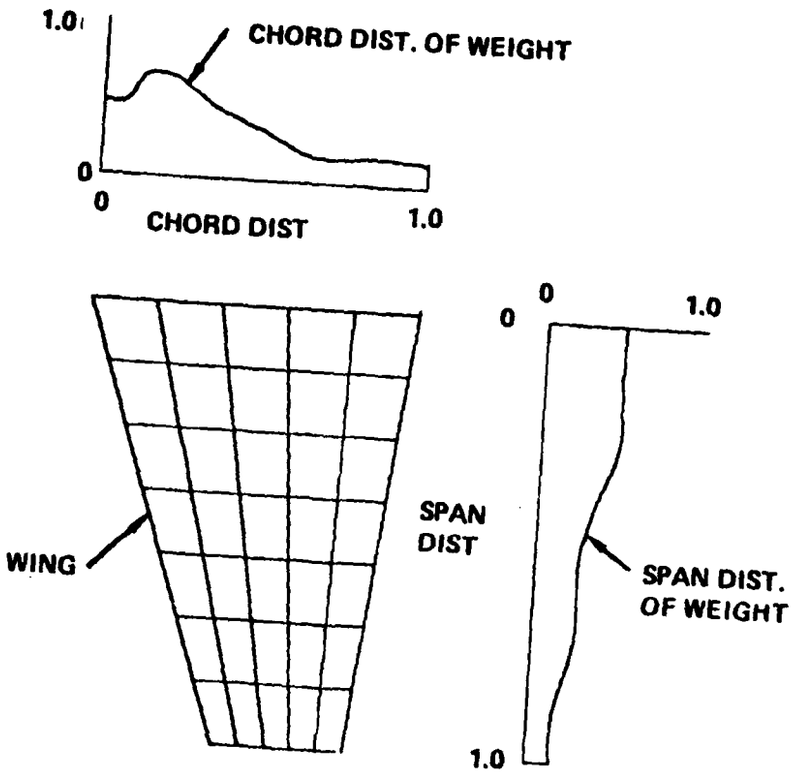


CONSTANT THICKNESS

VORTEX - LATTICE MODELING

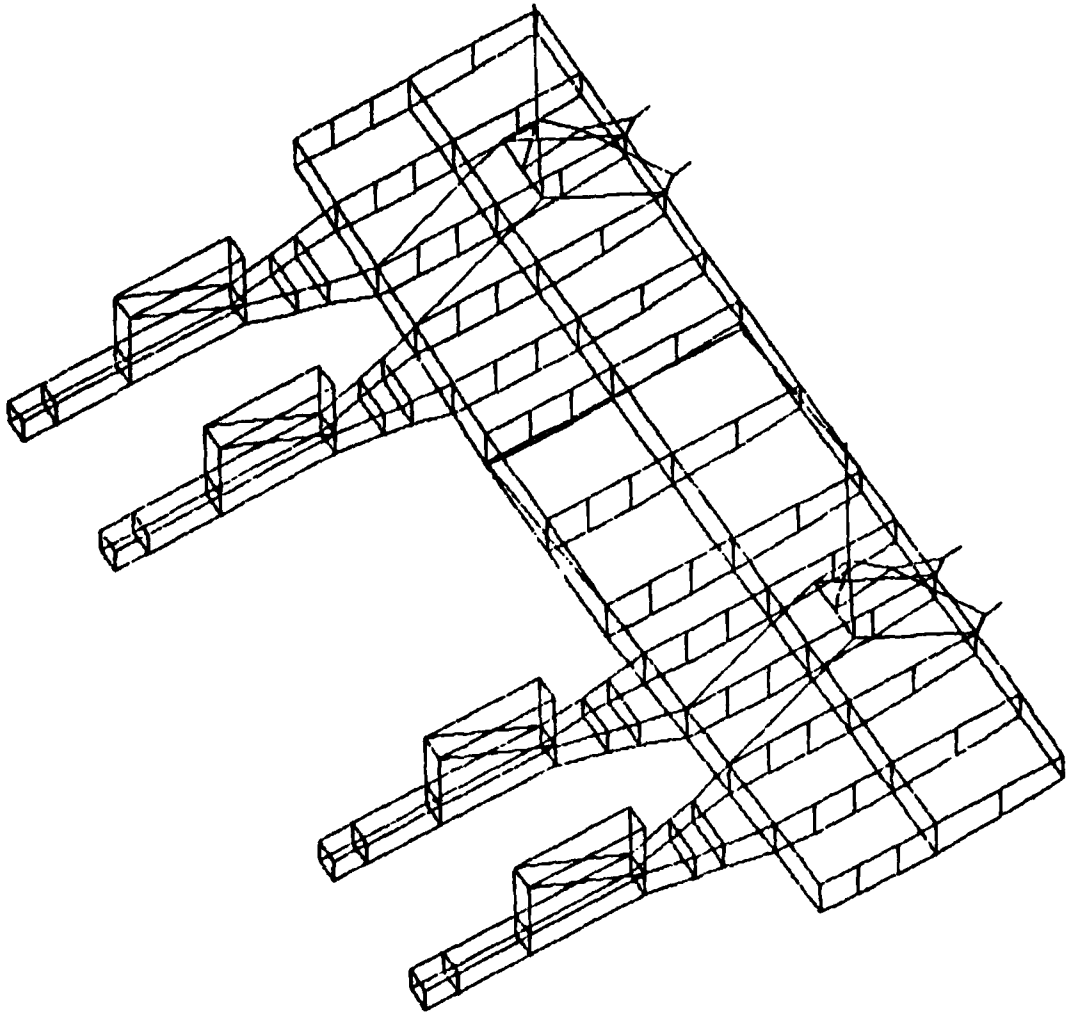


MASS DISTRIBUTION

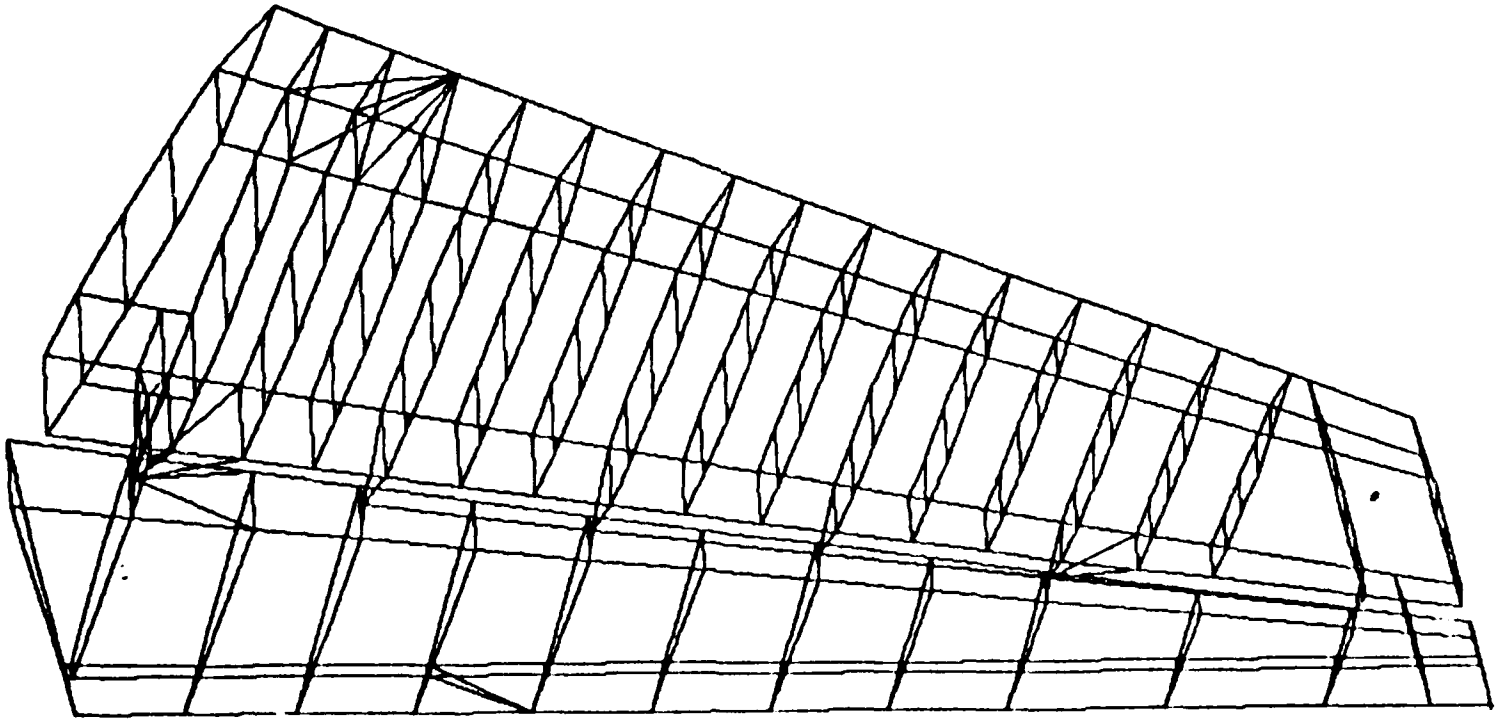


SUB-DIVIDED WING WITH WEIGHT CURVES

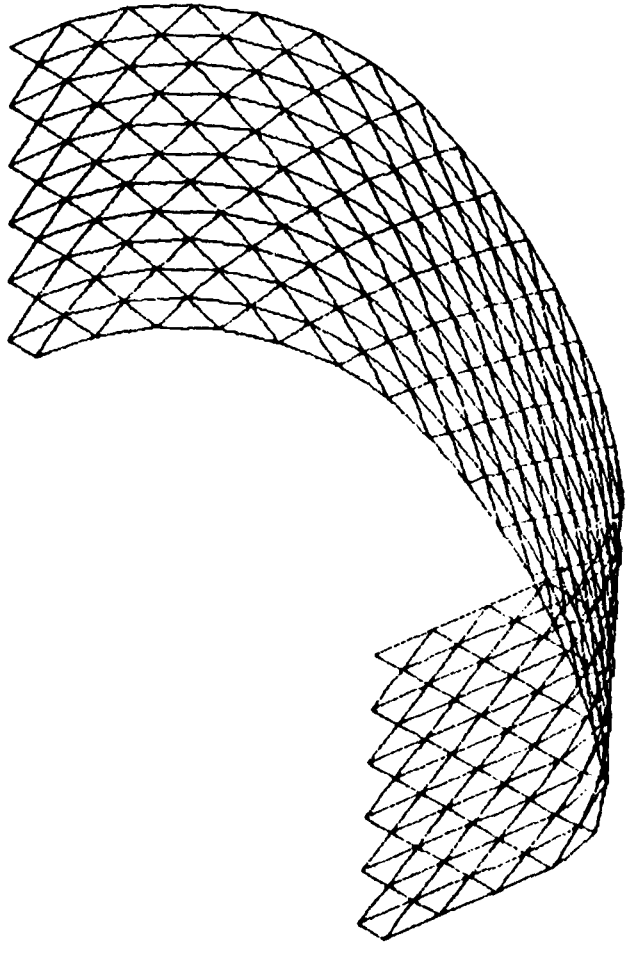
VSTOL WINGBOX



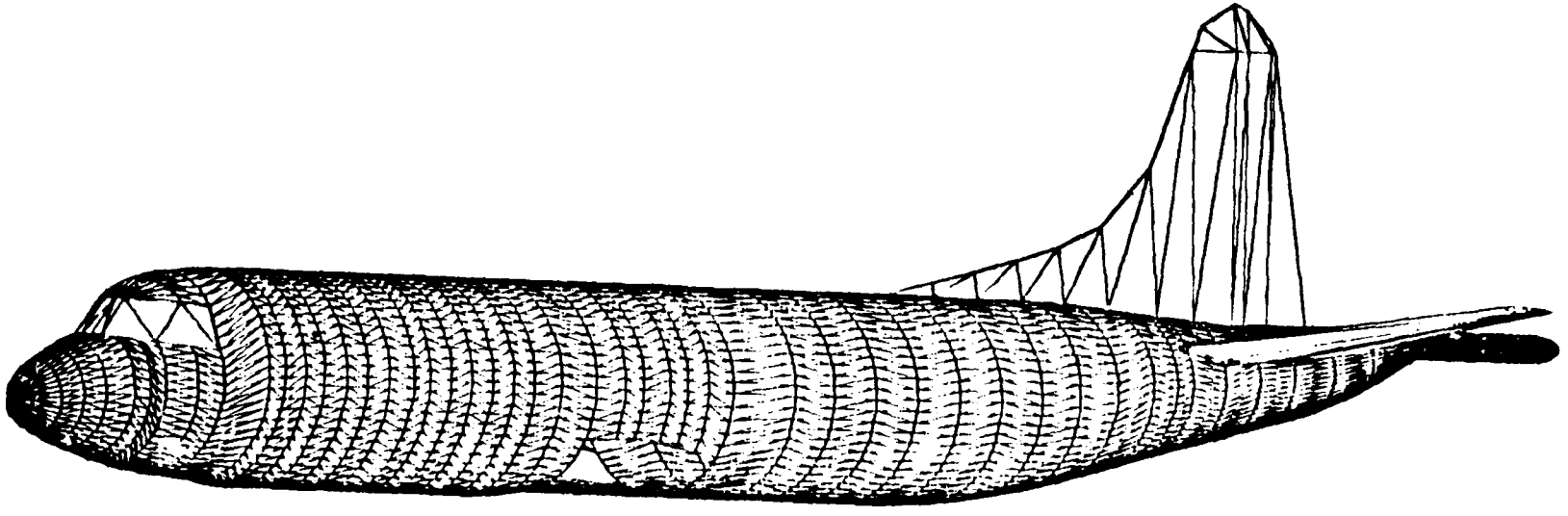
L-1011 VERTICAL FIN



COMPOSITE STRUCTURES



SURVIVABILITY MODELING



VIEW FROM 45 0

P-3C SURVIVABILITY STUDIES: AN APPLICATION OF COMPUTER-AIDED DESIGN

Donald E. Tuttle
and
Kimber L. Johnson
Lockheed-California Company
Burbank, California

P-3C SURVIVABILITY STUDIES: AN APPLICATION OF COMPUTER-AIDED DESIGN

Donald E. Tuttle
and
Kimber L. Johnson
Lockheed-California Company
Burbank, California

The P-3C is an antisubmarine warfare (ASW) aircraft with an expanding role in antisurface warfare (ASUW). This expanding role has increased concern over the survivability of the aircraft during encounters with surface combatants and with long-range fighter aircraft. Additionally, the capability exists for future arming of submarines with underwater launched anti-air missiles.

Lockheed is currently conducting studies for the Navy on the vulnerability of the P-3C. We are also studying improvements that can be used to increase the overall survivability of the aircraft and improve its effectiveness in the ASW and ASUW role.

Computer-aided design has been used in all aspects of the analysis. The accompanying viewgraphs indicate some of the areas studied.

Mission analysis and force requirements studies are based on analysis of encounters occurring during global warfare. ASW operations occur in three areas: along barriers that are used to monitor traffic through choke points such as exist between Great Britain and Greenland, along convoy routes, and in open sea areas where ballistic missile submarines operate. The world map indicates these operating areas and the potential for long-range Soviet aircraft operating in an armed role to act against the patrol aircraft. Additional threats exist when the aircraft is used in a surface search role where encounters with surface forces can subject the aircraft to surface-to-air missiles (SAM) and anti-air artillery (AAA).

The geometric model for assessing aircraft vulnerability was created using the Lockheed CADAM* system. Aircraft "drawings" were accessed and data points put in a temporary data set within CADAM. The data was then copied into a new data set and at the same time formatted for RAWGEN input thru a separate subroutine. Components within the aircraft were modeled using standard shapes such as cylinders or boxes.

* Registered trademark of the Lockheed Corporation

Survivability studies performed include the effects of susceptibility reduction through use of ESM, ECM, and IRCM. These studies have included analysis of the effects on the P-3C and on a new design alternative called the MPA. Also studied have been the effects of adding alternative lethal defense systems including the Phoenix, Sparrow or a conceptual small anti-missile missile. These studies have been carried out to ascertain the attrition levels and the expected life cycle costs of the various concepts with differing threat levels.

The broad range of studies carried out in this program are based on using computers as an aid in design. Computers at Lockheed provide the capability for broad-based comprehensive survivability studies. These studies are continuing in conjunction with Navy studies to define an Advanced P-3 aircraft that will be both effective and combat survivable.

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SURVIVABILITY/VULNERABILITY

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OBJECTIVES

- TO ASSESS THE CURRENT STATE OF THE P-3 SURVIVABILITY

- TO IDENTIFY LIKELY THREAT IMPROVEMENTS IN NEXT FIFTEEN YEARS

- TO IDENTIFY AND EVALUATE P-3 MODIFICATIONS AND TACTICS WHICH WILL MAINTAIN P-3 EFFECTIVENESS IN A HOSTILE ENVIRONMENT

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PATROL AIRCRAFT S/V TRENDS
1915 – 1981

- PRE-WORLD WAR II: S/V OF RISING CONCERN
- WORLD WAR II: S/V PEAK
- POST-KOREAN WAR: S/V REGRESSION
- P-3 AIRCRAFT: 1955 "UNDEFENDED AREA" CONCEPT
- THREAT TRENDS OMINOUS

S/V IMPROVEMENT REQUIRED

S/V CHARACTERISTICS

CURRENT P-3 FLEET

- MET 1955 "UNDEFENDED AREA" LAND PLANE SCR
- S/V DESIGN - SECONDARY FUNCTION OF FLIGHT SAFETY
  - FAIL-SAFE STRUCTURE: +3.0g −1.0g
  - CONVENTIONAL FLIGHT CONTROL SYSTEM
  - WET WING - 4 INTEGRAL TANKS
  - PRESSURIZED FUSELAGE
  - NO ARMOR
  - NO DEFENSIVE ARMAMENT
  - ESM — SUBMARINE SIGNAL INTERCEPTION

CURRENT NAVY PLANS: RETAIN IN FLEET UNTIL ~ 2025

SURVIVABILITY GOALS

- MINIMAL COMPROMISE OF ESSENTIAL DESIGN CRITERIA
- COST EFFECTIVE TECHNIQUES IN TOTAL SYSTEM CONTEXT
- CAPABILITY TO PERMIT INDEPENDENT ACCOMPLISHMENT OF MISSIONS
- CAPABILITY TO RETURN TO BASE GIVEN DEFINED HIT

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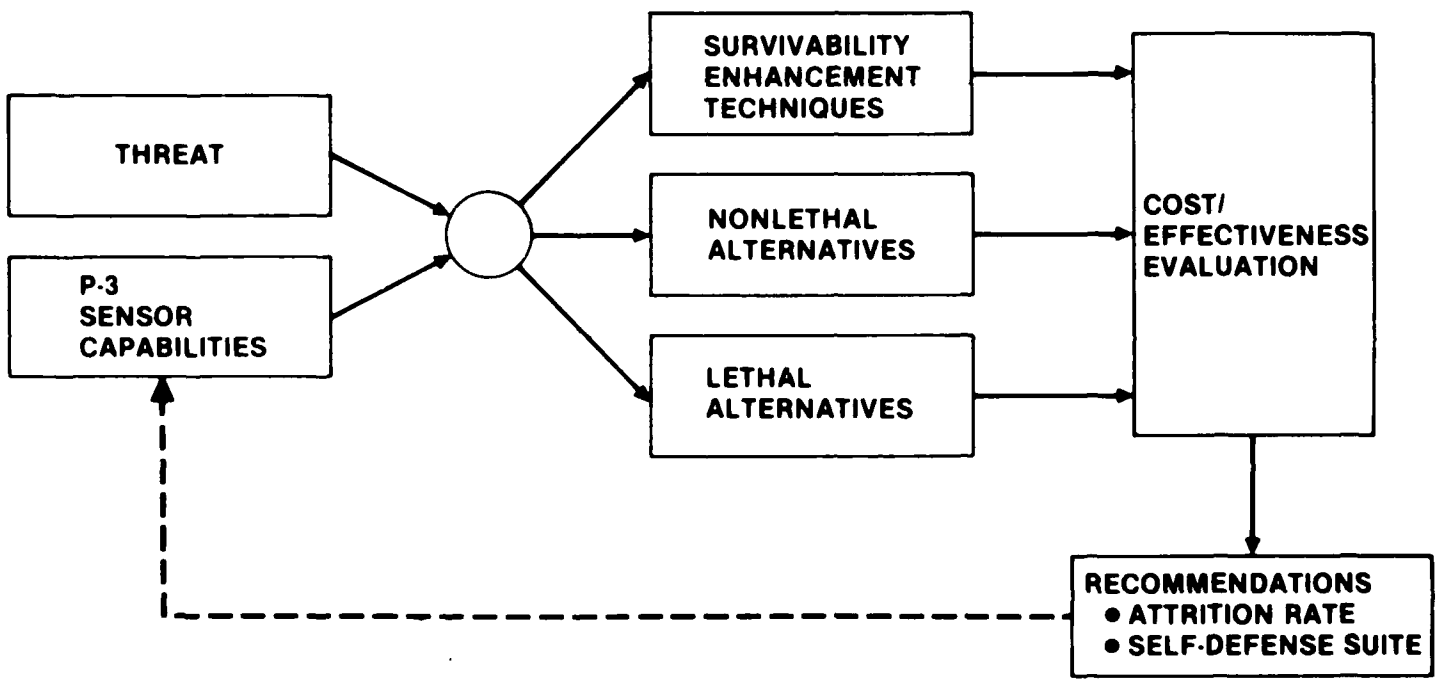
SELF DEFENSE STUDIES



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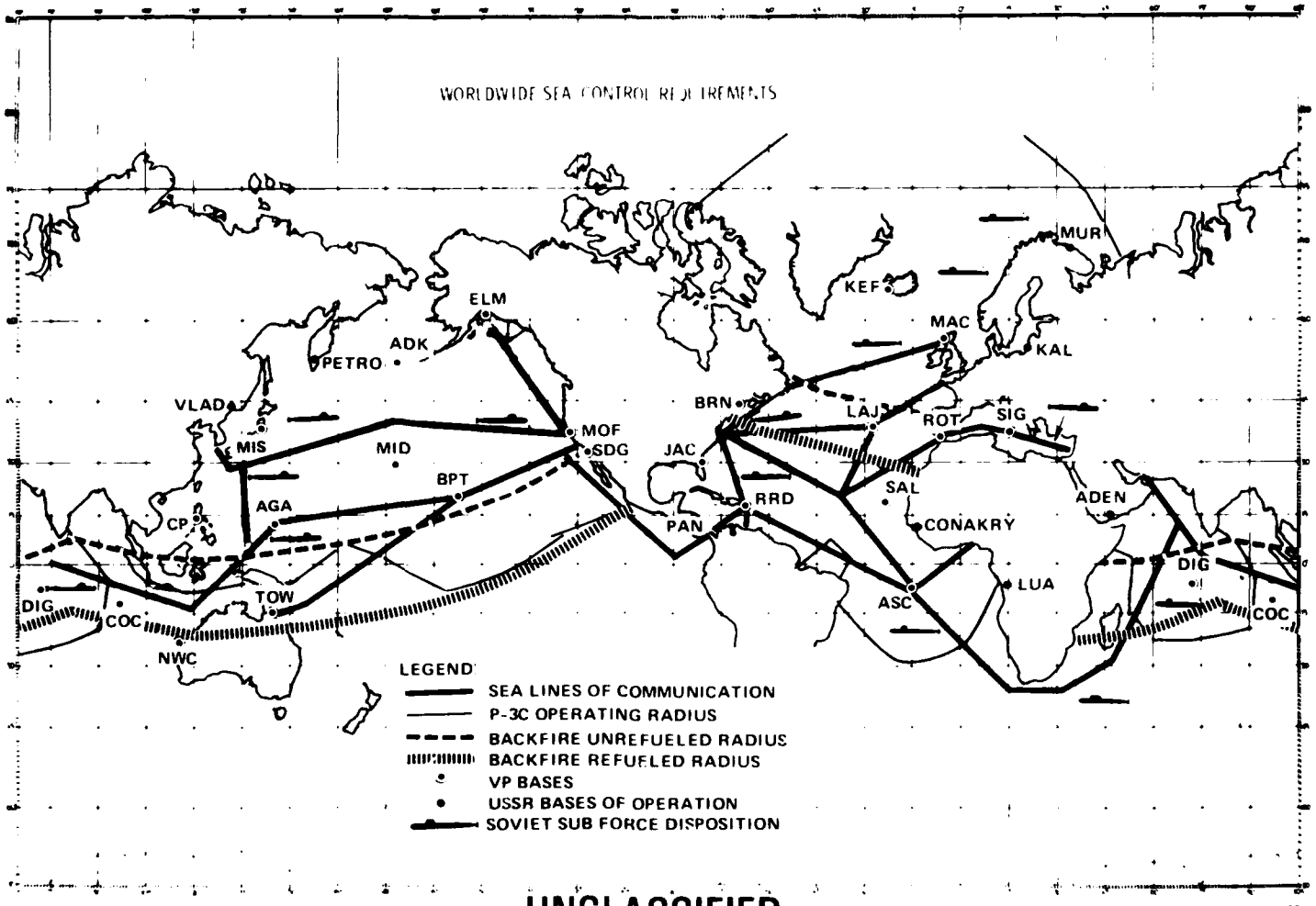
WORLDWIDE SEA CONTROL REQUIREMENTS

PATROL AIRCRAFT PERSPECTIVE



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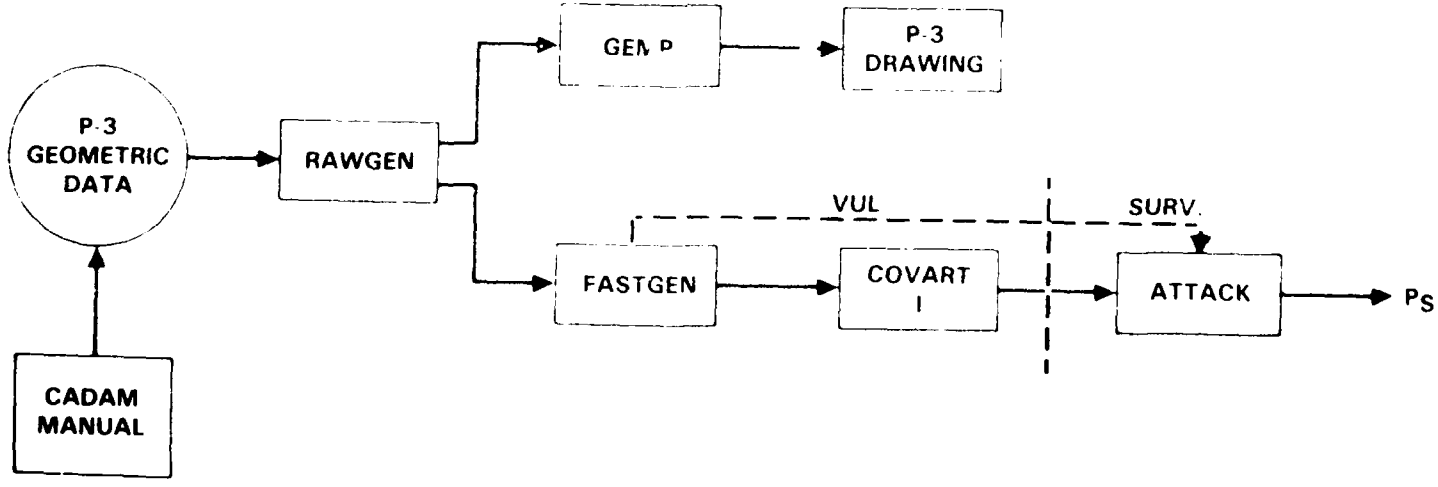
S/V THREAT MECHANISMS

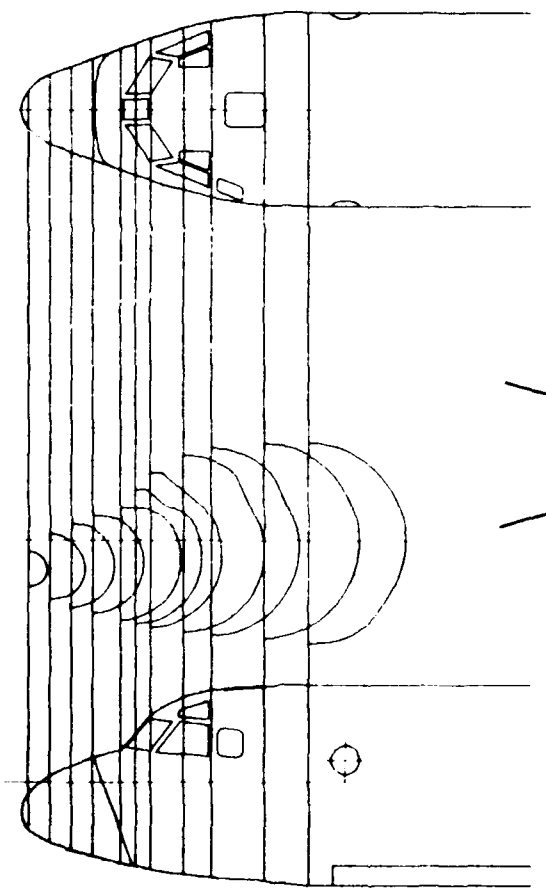
THREAT	HAZARD
GUNS	
AIR - AIR	BULLETS
	INCENDIARY
SHIP AA	
MISSILES - RADAR - IR	
AIR - AIR	FRAGMENTS
	BLAST
SHIP - AIR	
NUCLEAR	BLAST
	GUST
	THERMAL
	TREE
	EMP

S/V METHODOLOGY

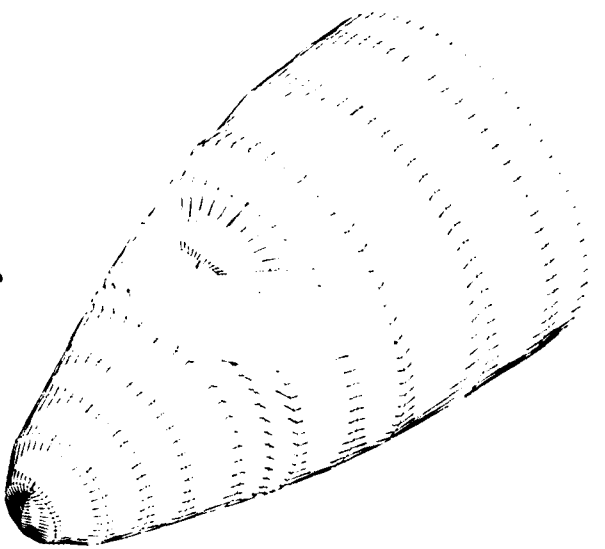
CADAM	COMPUTER AUGMENTED DESIGN AND MANUFACTURING CALAC COMPUTER GRAPHICS SYSTEM	RAWGEN	COMPUTER GEOMETRIC CO ORDINATE DATA FOR INPUT TO FASTGEN	COVART	COMPUTES VULNERABLE AREA (AV) BASED ON FAST GEN SHOTLINE ARRAYS AND PERTINENT THREAT DATA
GEMP	GEOMETRIC MODEL PLOTTING PROGRAM	FASTGEN	APPLIES SHOTLINES TO AIR CRAFT MODEL	ATTACK	COMPUTES SINGLE SHOT PROBABILITY OF KILL VERSUS CEP AND MISS DISTANCE



CADAM TO RAWGEN



CAD
GEN



VIEW FROM 45 45

MAD 81-517 A

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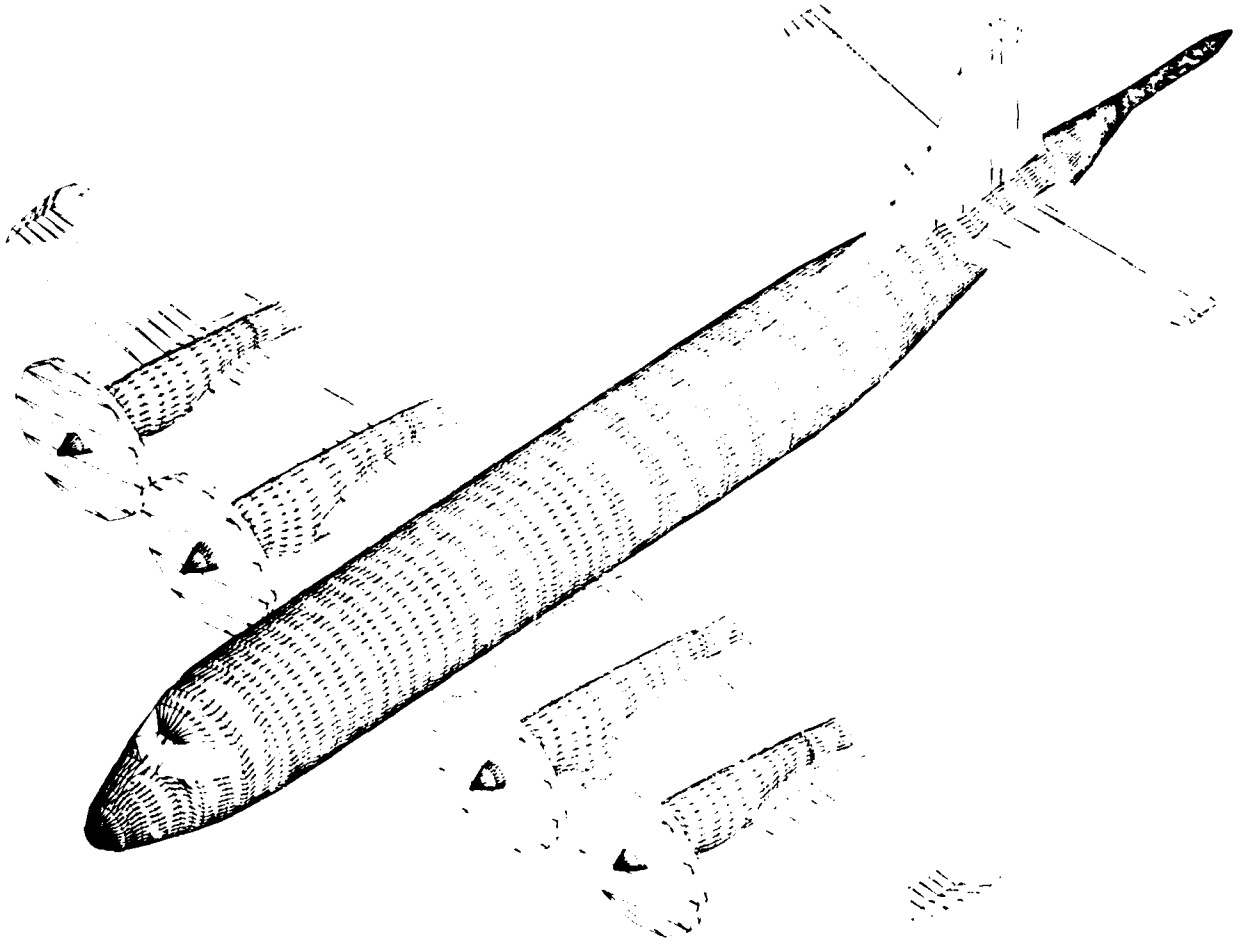
P-3 SURVIVABILITY

JTCG/AS — CADAM MODELING



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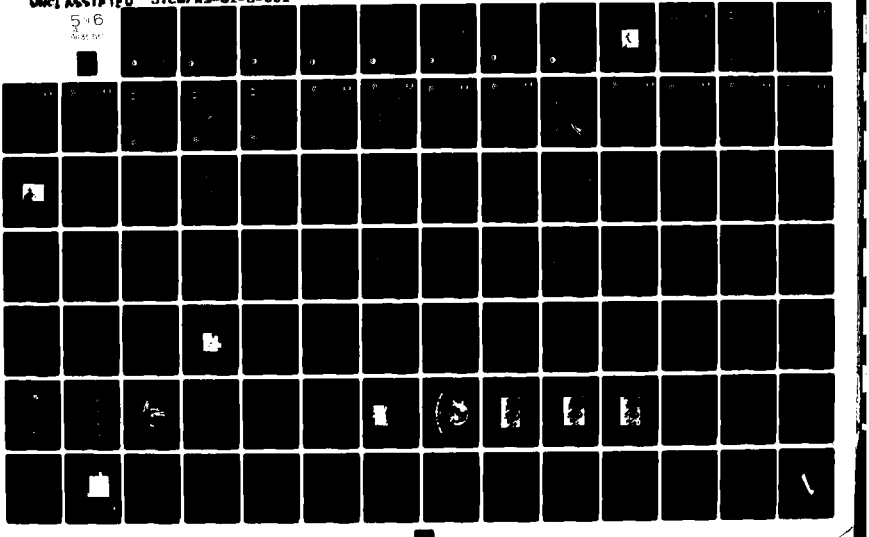
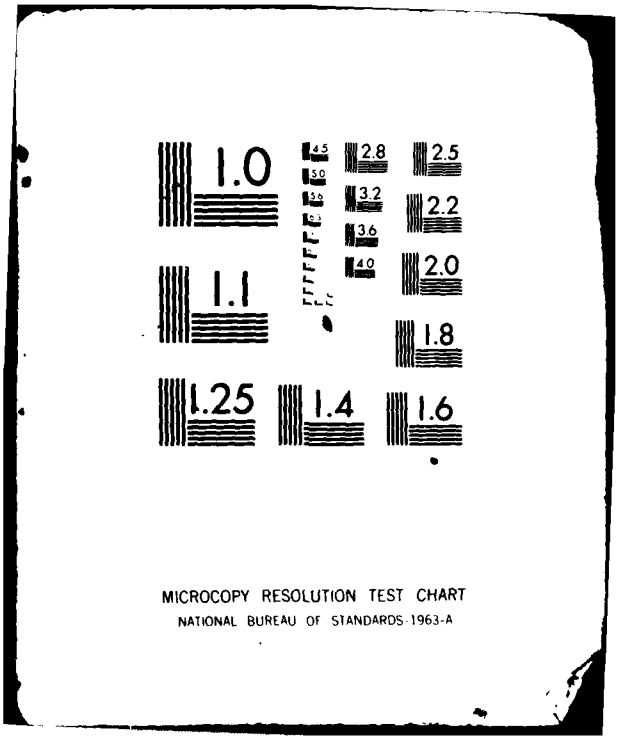
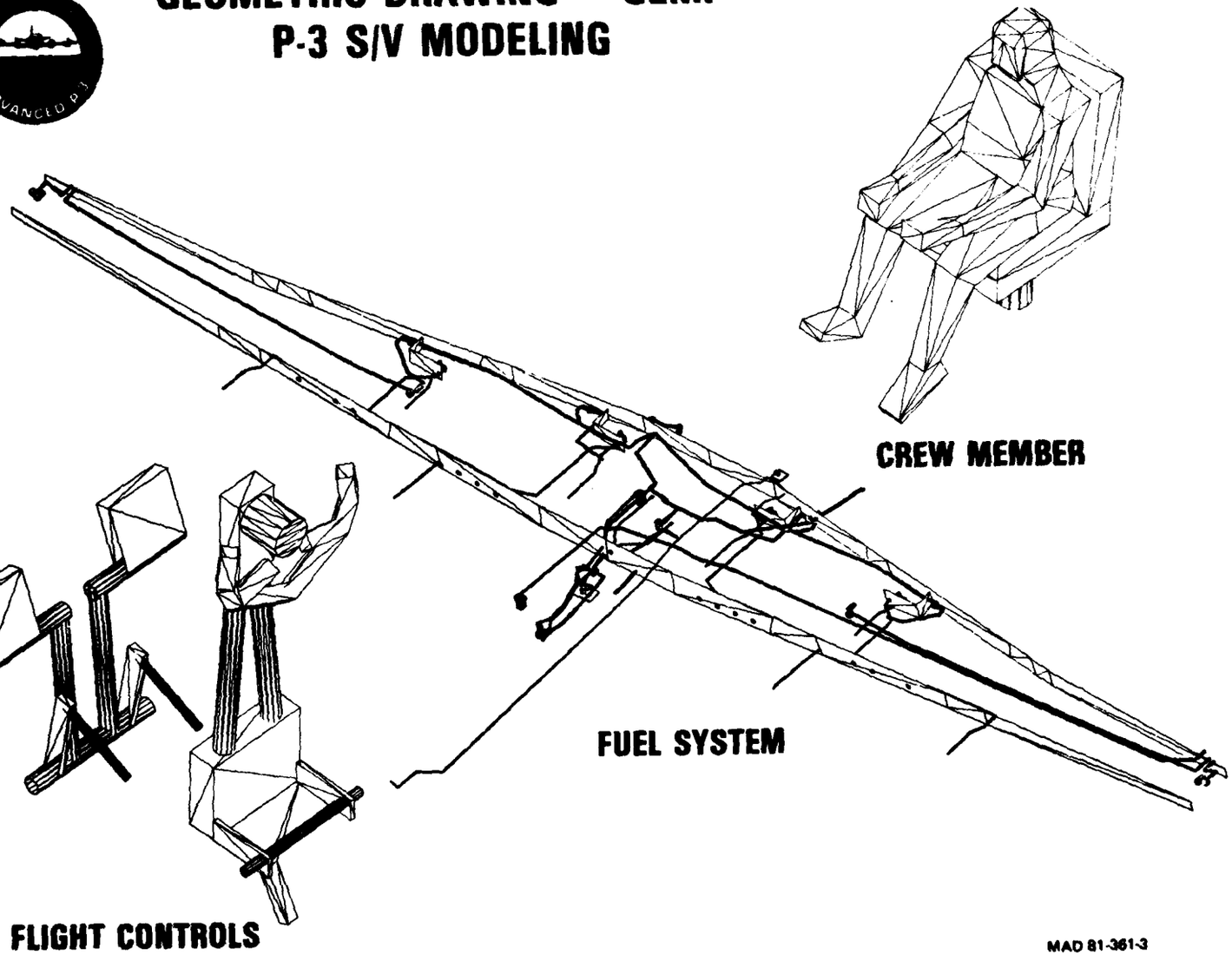
MAD 81-509-4

AD-A113 556 JOINT TECHNICAL COORDINATING GROUP ON AIRCRAFT SURVIV--ETC F/G 1/3
PROCEEDINGS: A WORKSHOP IN SURVIVABILITY AND COMPUTER-AIDED DES--ETC(U)
1981
UNCLASSIFIED JTCG/AS-81-O-001 NL




1.0
1.1
1.25
1.4
1.6
1.8
2.0
2.2
2.5
2.8
3.2
3.6
4.0
4.5
5.0
5.6
MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

GEOMETRIC DRAWING – GEMP
P-3 S/V MODELING



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P-3 S&V ASSESSMENTS

	VULNERABILITY	PROTECTION INHERENT IN P-3 DESIGN	POTENTIAL VR IMPROVEMENTS
FUEL SYSTEM			
TANKS	FIRE OR EXPLOSION	NONE	FOAM IN TANKS
DRY BAYS	FIRE OR EXPLOSION	NONE	FOAM IN BAYS
FUEL LINES	LEAKS & FIRES	FUEL LINES INSIDE TANKS TRANSFER & CROSS FEED	–
FLIGHT CONTROLS	LOW EXCEPT ELEVATORS COULD BE JAMMED IN POSITION	REDESIGN MECHANICAL CONTROLS	–
STRUCTURAL	AIRFRAME DESIGN VALIDATED BY TESTS FOR FAILSAFE CRITERIA	–	–
PROPULSION	NO PHYSICAL PROTECTION	FIRE EXTINGUISHERS 3 ENG MISSION CAPABLE 2 ENG RETURN FLT	–
AVIONICS	TO 3 KV/m EMP	DESIGNED & TESTED FOR LIGHTNING	SHIELDING DESIGN FOR EMP CRITERIA
CREW	NO DEDICATED PROTECTION	OTHER CREW MEMBERS CAN TAKEOVER	CONSIDER WIND-SHIELD PROTEC-TION, ETC.
ELECTRICAL	LOW	4 GENERATORS WORKAROUND DESIGN	DESIGN FOR EMP

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P-3 SELF DEFENSE OPTIONS

- ESM TO KEEP P-3 OUT OF SAM ENVELOPE AND ALLOW STANDOFF ATTACK OF SURFACE THREATS

- ESM & ECM TO PROVIDE WARNING AND FORCE ATTACKING AIRCRAFT INTO CLOSE RANGE WHERE AMRAAM OR SPARROW TYPE MISSILES CAN BE USED

- DEPENDENT ON SPW DEVELOPMENTS SMALL SHORT RANGE AMM's ARE BEING CONSIDERED

SPW — JOINT NAVY/AF SELF PROTECTION WEAPON PROJECT OFFICE AT EGLIN AFB

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P-3 RADAR/IR SUSCEPTABILITY

- TARGET SIZE (RADAR)
  - RELATIVELY LARGE RADAR CROSS SECTION
    - SMALLER THAN B-52/C-130
    - LARGER THAN FIGHTER
    - CAN AND WILL BE DETECTED AND TRACKED
    - VULNERABLE WITHOUT ECM
- IR SIGNATURE
  - INFRARED CROSS SECTION SIMILAR TO C-130
    - IR THREAT ENVELOPE SLIGHTLY DIFFERENT ORIENTATION
    - DEFINITELY POSSIBLE TO DETECT AND TRACK WITHIN MISSILE FIRING ENVELOPE
    - VULNERABLE WITHOUT IRCM

MAD 81-84-1-4

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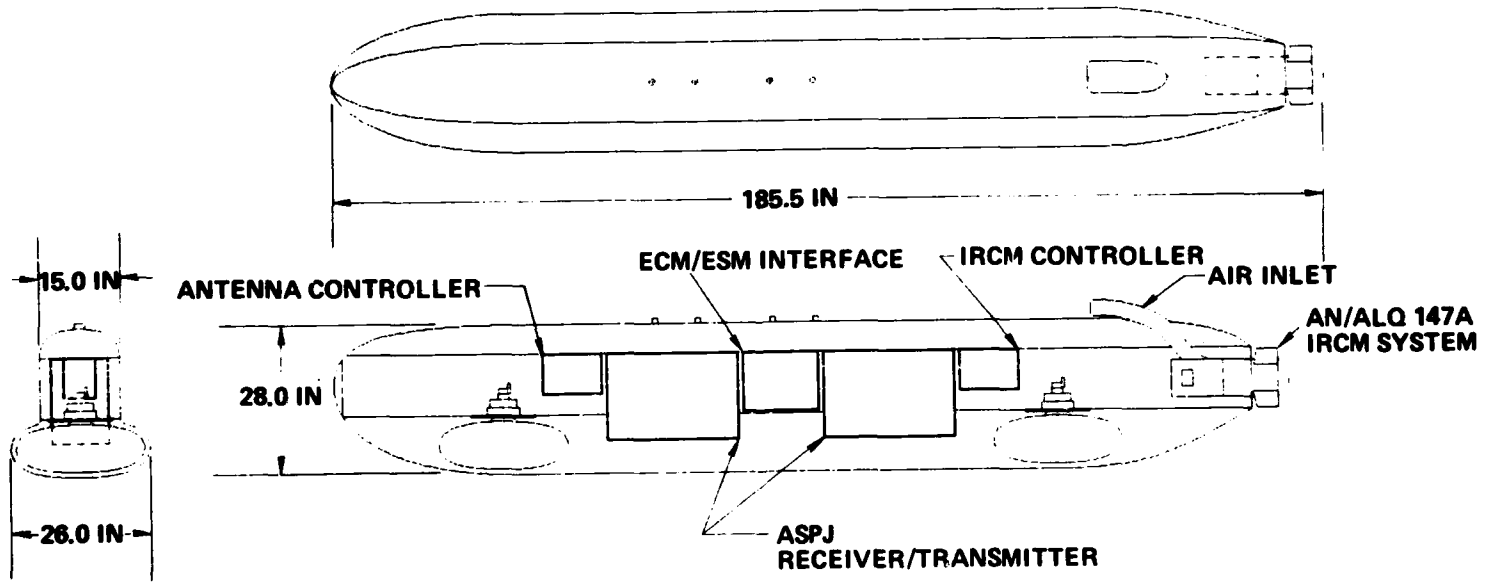
ECM/IRCM POD



MAD 81-149-2

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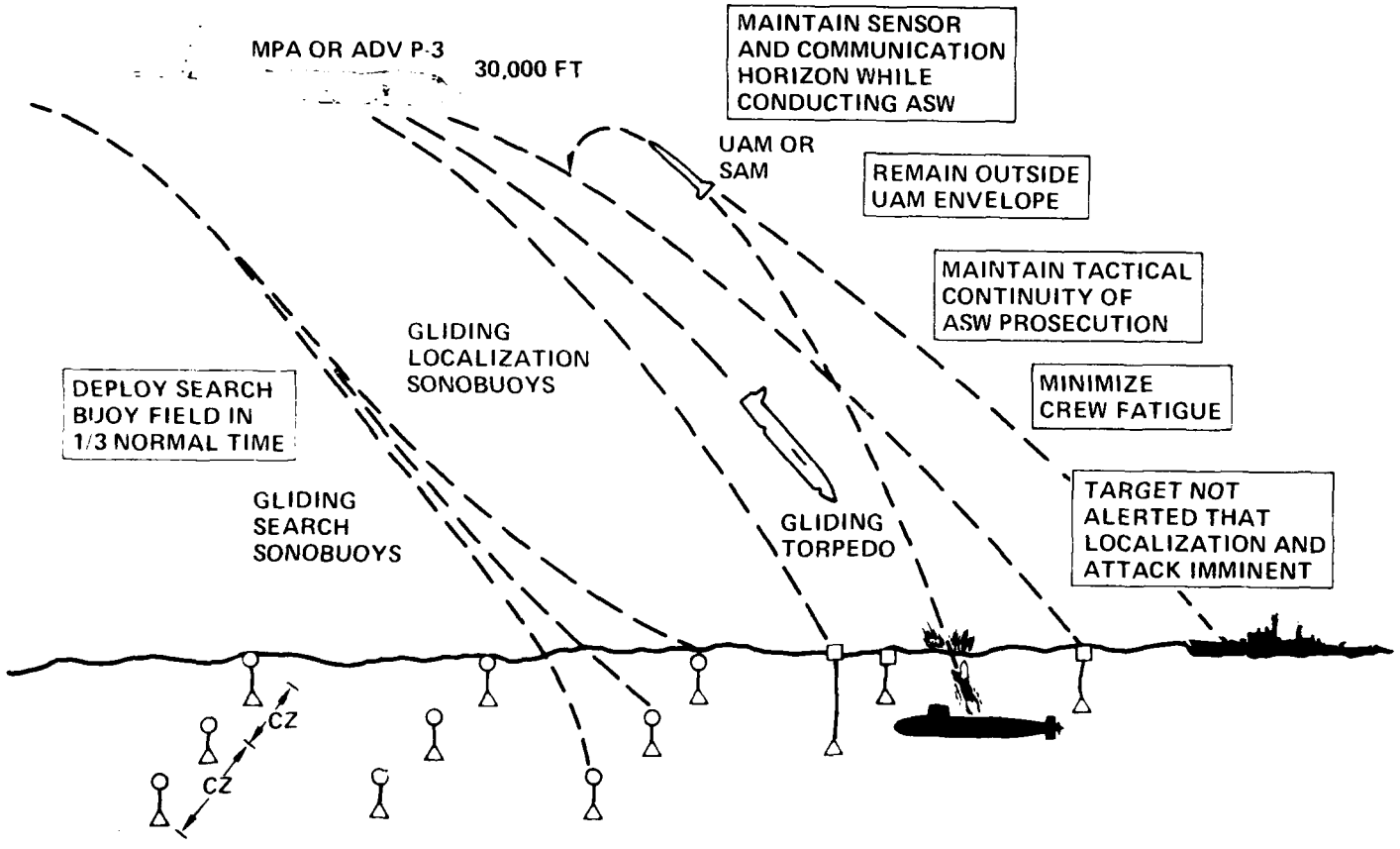
HIGH ALTITUDE/STANDOFF ASW



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S/V ASSESSMENT

- **CONCERTED EFFORT TO EXAMINE KEY TRADEOFFS**
  - SURVIVABILITY ENHANCEMENT
  - NONLETHAL SELF-DEFENSE
  - LETHAL SELF-DEFENSE

- **TRADEOFF METHODOLOGY PERMITS QUANTITATIVE TRADE-OFFS**
  - COST OF SELF-DEFENSE AND SURVIVABILITY ENHANCEMENT SYSTEMS

    VS.

  - COST OF ATTRITION FOR EQUAL FORCE EFFECTIVENESS

- **ONGOING LOCKHEED INTERACTION IN THIS VITAL AREA WITH:**
  - NAVAIR (PMA-240), NWC CHINA LAKE, NSWC WHITE OAK, NPS MONTEREY, JTCG/AS, USAF
  - GD, GE, HUGHES, SANDERS

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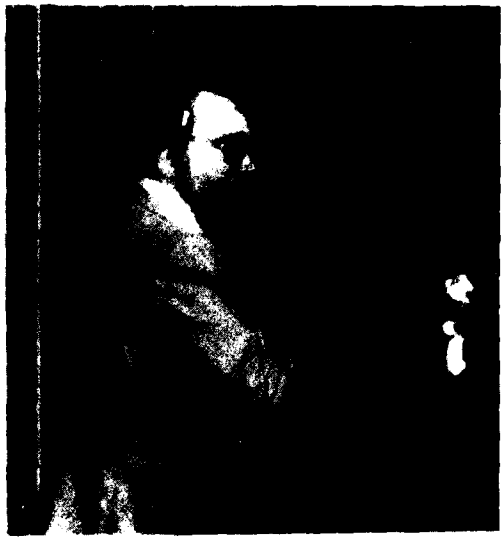
CONCLUSIONS

- THREAT TRENDS DRIVE ADVANCED P-3 S/V DESIGN
- SIGNIFICANT S/V IMPROVEMENT MANDATORY
- TRADE-OFFS COMPLEX
- COMPUTER AIDED DESIGN ESSENTIAL TO PROCESS

INTERACTIVE GRAPHICS FOR DISPLAY AND MODIFICATION OF TARGET DESCRIPTIONS

Earl P. Weaver, Vulnerability/Lethality Division
Michael J. Muuss, Ballistic Modeling Division
ARRADCOM
Ballistic Research Laboratory
Aberdeen Proving Ground, Maryland



EARL P. WEAVER,
ARRADCOM

ARRADCOM
Ballistic Research Laboratory
Aberdeen Proving Ground
Maryland

INTERACTIVE GRAPHICS FOR DISPLAY AND MODIFICATION OF TARGET DESCRIPTIONS (U)

Earl P. Weaver — *Vulnerability/Lethality Division*
Michael J. Muuss — *Ballistic Modeling Division*

12 Nov 1980

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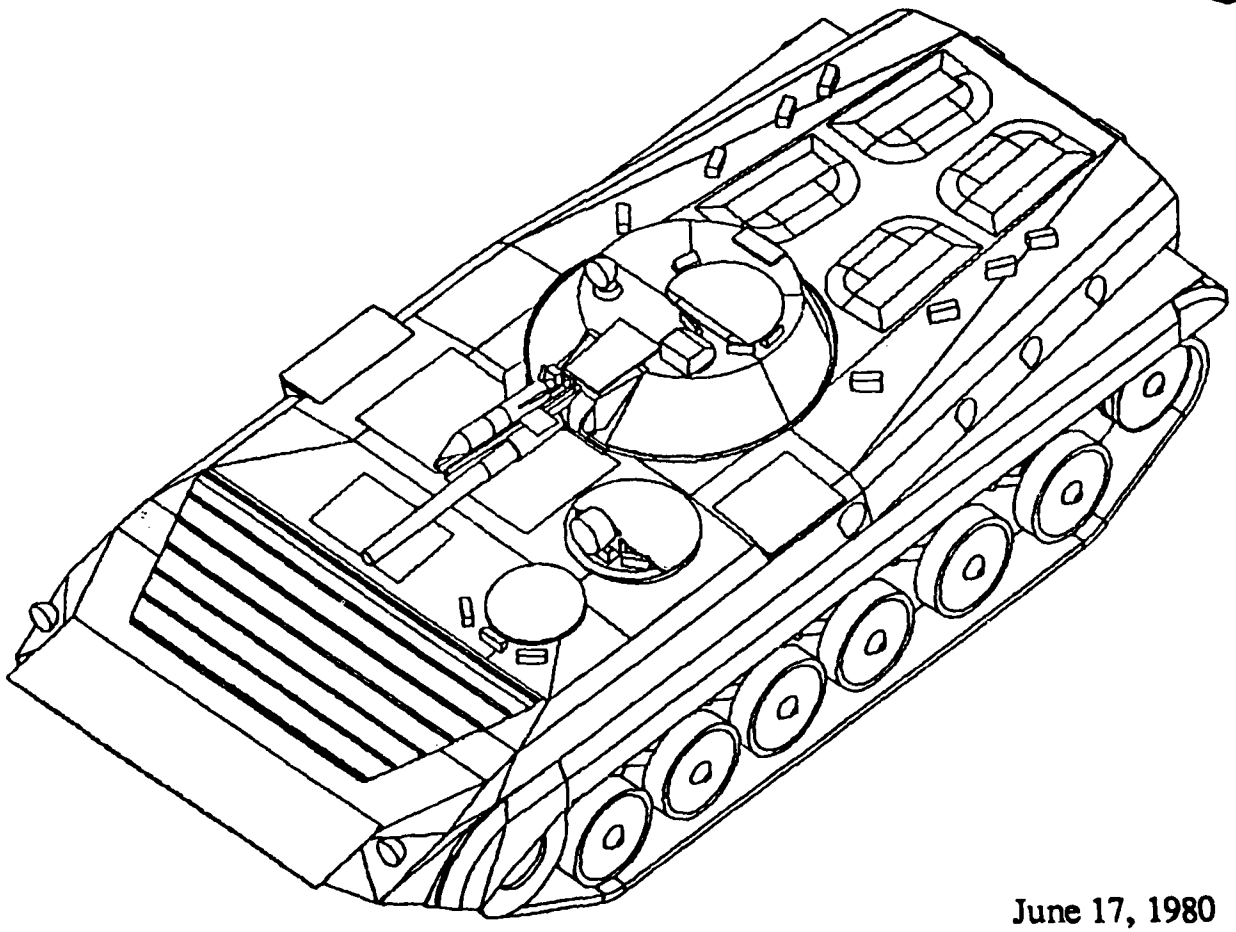


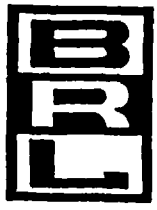
June 17, 1980

TARGET MODELS PROVIDE:

- INPUT TO VULNERABILITY ASSESSMENT CODES
  - *Components/Compartments encountered*
  - *Angle of obliquity at point of impact*
  - *Component material*
  - *Component's line-of-sight thickness*
  - *Angle of exit*

- INFORMATION FOR ANALYSIS
  - *Weights*
  - *Volumes*
  - *Centers of gravity*
  - *Moments of inertia*
  - *Presented areas*
  - *Pictures*

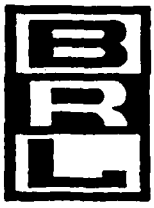
June 17, 1980



BASIC FUNCTIONS OF A TARGET DESCRIPTION SYSTEM

- Represent the geometric/physical system under study by a model
- Create, delete, and change the model
- Display a representation of the model
- Analyze the model and output calculations based on it

April 30, 1980



COM-GEOM

COMBINATORIAL GEOMETRY

- LIBRARY OF SHAPES
  - *Boxes*
  - *Cylinders*
  - *Spheres*
  - *Cones*
  - *Pyramids*
  - *Wedges*
  - *N-Faced Arbitrary Polyhedra*
  - *Others*

- COMBINE SHAPES USING
  - *Intersection*
  - *Subtraction*
  - *Union (OR)*

June 17, 1980

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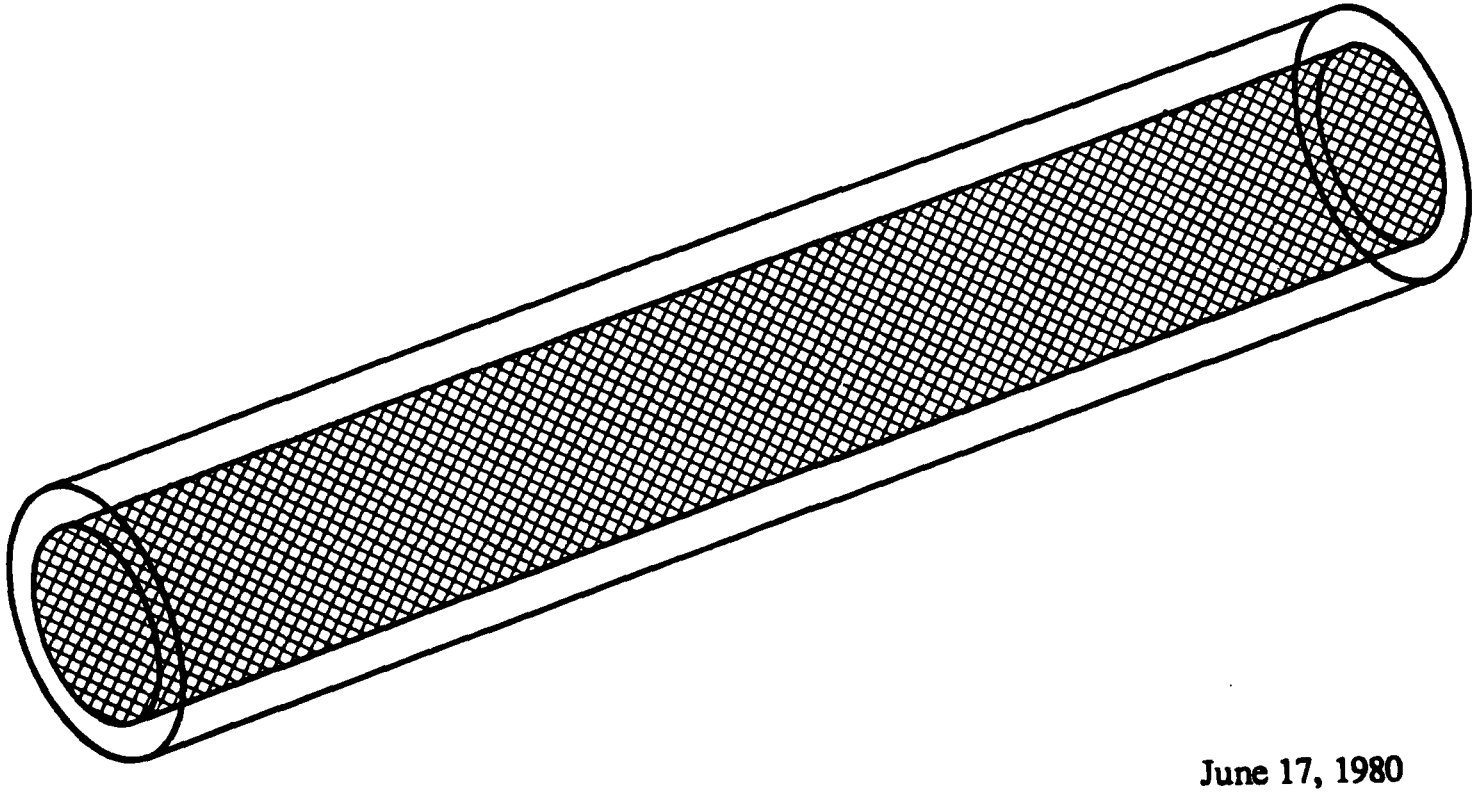
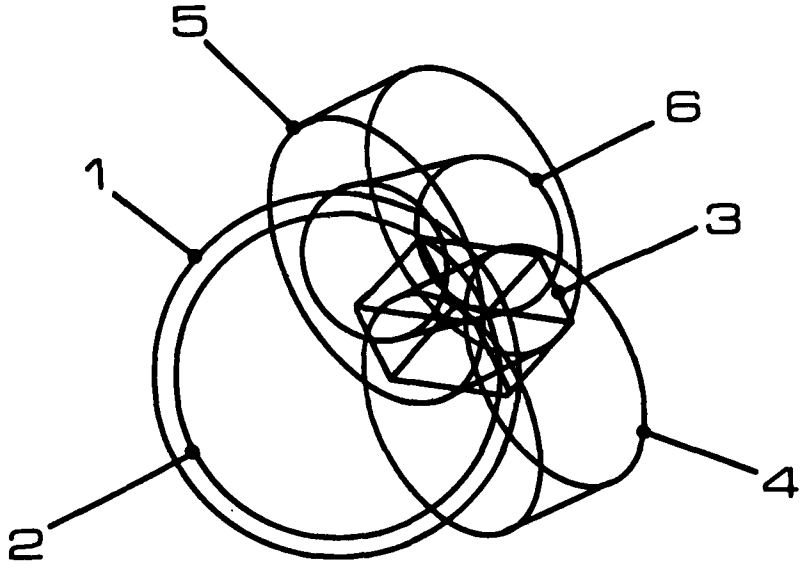


June 17, 1980



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June 17, 1980

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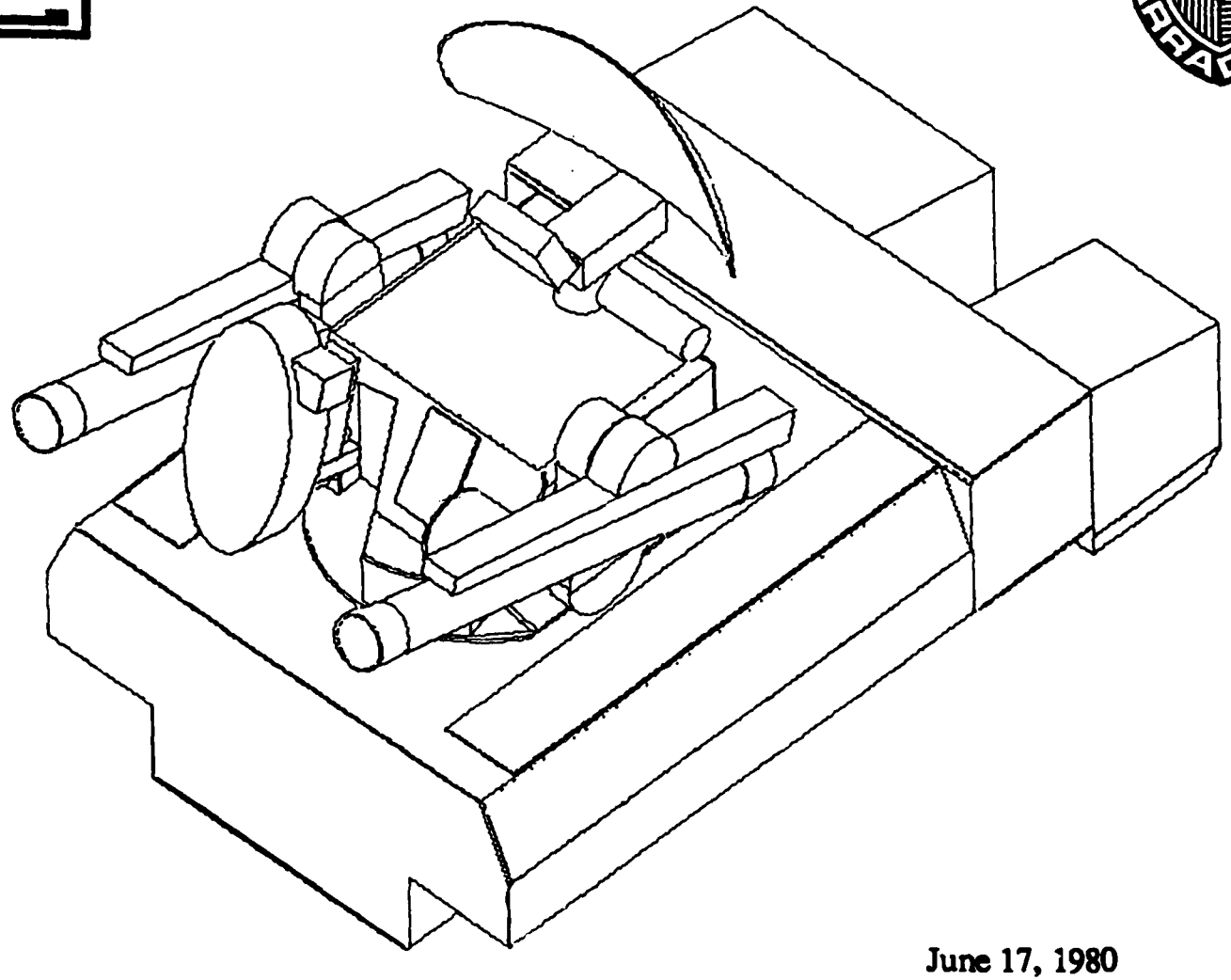


June 17, 1980

GENERATING
A TARGET DESCRIPTION

- Determine "level of detail"
- Decide on construction of component
- Prepare data
- Validate model
  - *Check for overlap*
  - *Pictures*
  - *Shotlines*

April 30, 1980

PROBLEM AREAS

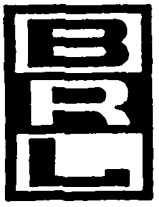
- Data Preparation
- Validation
- Modification

June 17, 1980

DESIGN OBJECTIVES

- **Real-time** functions
  - ✓ construction
  - ✓ viewing
  - ✓ modification
- Little or no explicit numerical input
- "Stock room parts bin" to eliminate redundant design work
- Interface to GIFT code

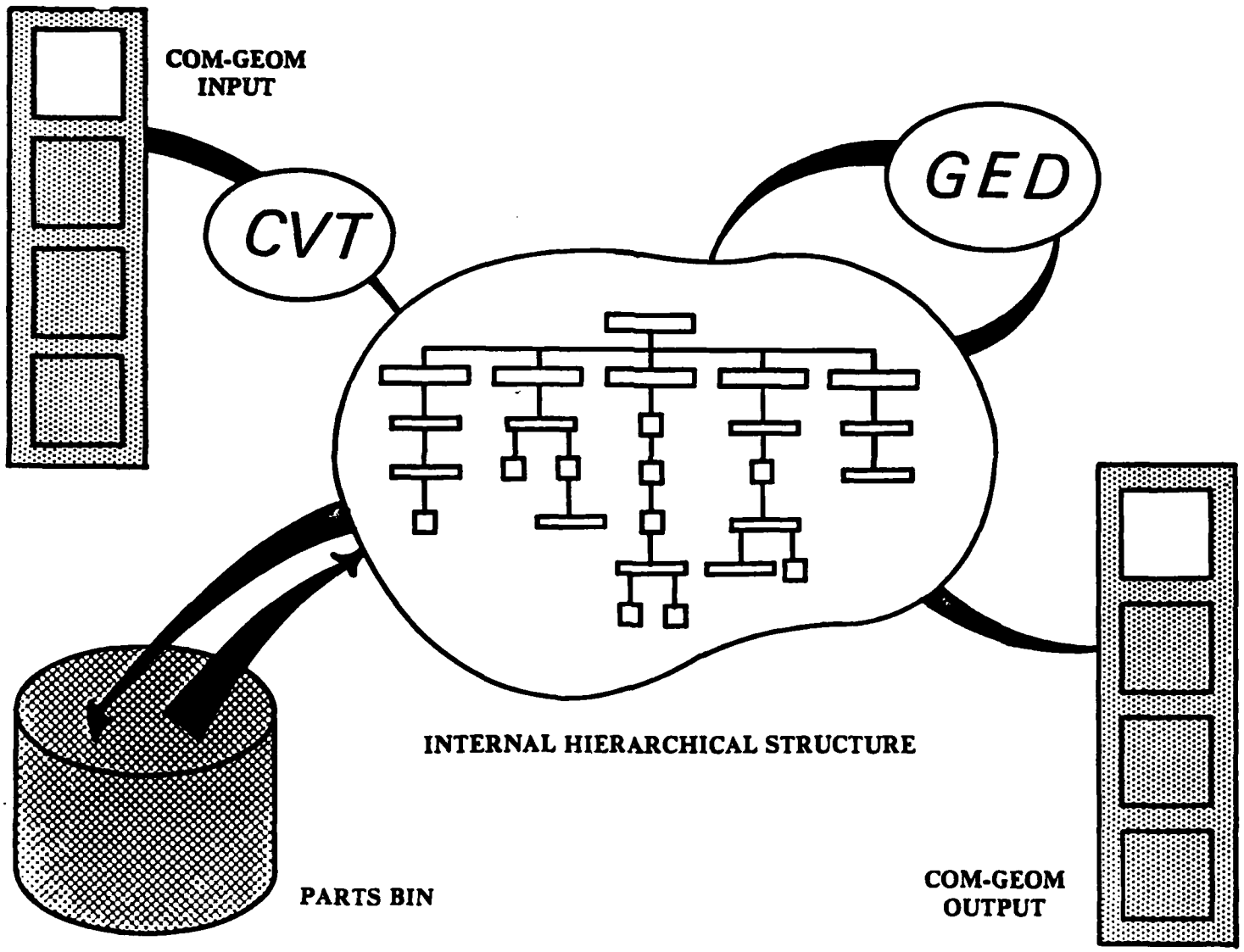
April 30, 1980



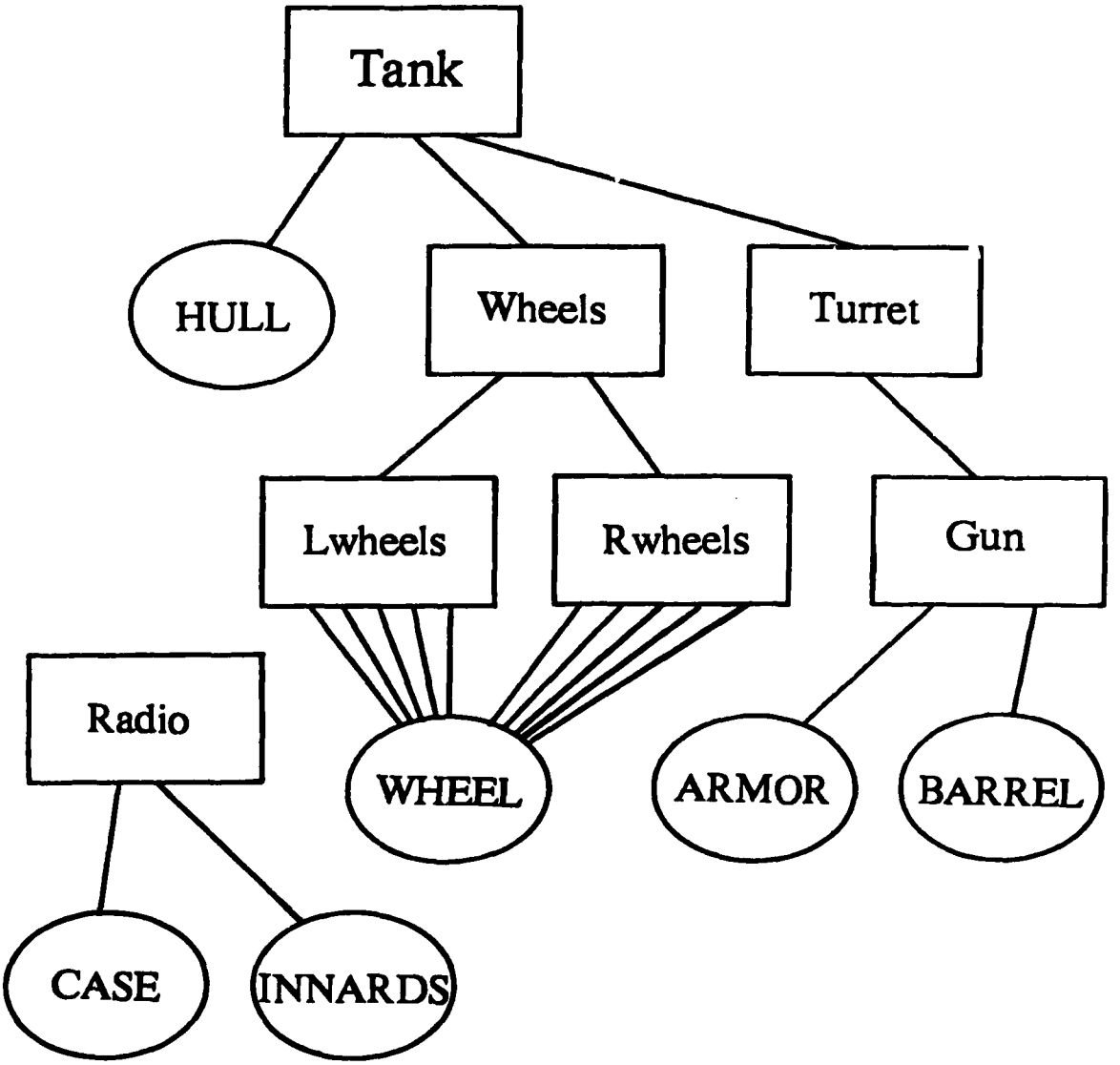
IMPLEMENTATION

- GENERALIZED COM-GEOM SOLIDS
  - *Arbitrary 8-vertex polyhedron*
  - *Truncated general cone*
  - *Ellipsoid of revolution*
- DISPLAY LIMITATIONS
  - *Draw only solids (Dashed lines indicate subtracted solids)*
  - *No hidden line/surface removal*
  - *No complex edge generation*
  - *No perspective view (Depth cueing by decreased intensity)*

June 17, 1980


COM-GEOM
INPUT
CVT
GED
INTERNAL HIERARCHICAL STRUCTURE
PARTS BIN
COM-GEOM
OUTPUT

HIERARCHICAL OBJECT STRUCTURE



June 17, 1980

GED Features

- DISPLAY
  - *Show/erase parts*
  - *Pan*
  - *Arbitrary viewpoint*
  - *Zoom*
  - *Preset views*
  - *Slicing plane*
  - *Save viewpoint*
- MANIPULATION
  - *Create and delete assemblies*†
  - *Rename assemblies*
  - *Copy solids*
  - *"Instance" assemblies*
  - *Move assemblies*
  - *Scale assemblies*
  - *Modify solids*

† *Assemblies = Solids or Combinations*

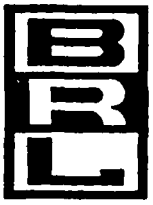
June 17, 1980

IMPLEMENTATION DETAILS

- The C structured programming language
- The **BRLNET-JHU/UNIX** † operating system
- Vector General refresh display
  - *32 K byte display memory*
- DEC PDP-11/34 computer
  - *96 K words MOS*
  - *80 Megabyte disk*

† *UNIX is a trademark of Bell Labs*

June 17, 1980



BENEFITS OF GRAPHICS EDITOR

- Cheaper, faster, more useful target models
- Ability to modify model in real-time
- "Stock room parts bin" eliminates duplication of effort
- Increased productivity of Target Modeling Specialists
- Vulnerability reduction studies practical
- Ability to quickly implement engineering changes

June 17, 1980

TO ACCESS SURVIVABILITY AND COMBAT DAMAGE IN AIRCRAFT DESIGN SELECTION

Paul T. Chan
Vought Corporation
Dallas, Texas

TO ACCESS SURVIVABILITY AND COMBAT DAMAGE IN AIRCRAFT DESIGN SELECTION

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Vought Corporation
Dallas, Texas

Vought's Aircraft Synthesis Analysis Program (ASAP) is a computerized synthesis model for conducting conceptual aircraft design and performance studies which include sizing, costing and optimization. To provide ASAP with effectiveness measures for use in parametric design tradeoffs (as inputs to the Optimization Module), Vought's Campaign Force Effectiveness Model (CFEM) was integrated into ASAP.

CFEM calculates the sortie rate capability of aircraft point designs, as influenced by mission time, aircraft attrition and down-time due to combat damage repairs and non-scheduled maintenance.

Input parameters include:

- Probability of aircraft loss inflicted by the defense
- Probability of aircraft damage inflicted by the defense
- Combat damage repair down-times and their distribution frequencies
- Non-scheduled maintenance down-times and their distribution frequencies.

CFEM also calculates force effectiveness based on:

- Payload radius
- Number of passes per sortie
- Number of sorites per day
- Expected number of targets killed per pass
- Initial force size
- Number of campaign days
- Weather conditions.

Outputs include a cumulative accounting of sorties generated, targets killed, aircraft losses, and ordnance delivered. The normalized effectiveness measure (in reference to equal force size or equal program cost) is passed over to ASAP's Optimization Module as a basis for parametric aircraft design tradeoffs.

The ASAP/CFEM methodology has been applied to the USAF Advanced Tactical Fighter Program. The ability of the combined methodology to handle a wide range of conceptual designs, and to establish successful point design selections, demonstrates the ASAP/CFEM's flexibility and usefulness. It is a valuable analytical tool for the computer-aided design technology.

This presentation is limited to a discussion of the CFEM model and its generation of force effectiveness as the objective function for the combined ASAP/CFEM integrated model.

To Assess Survivability and Combat Damage in Aircraft Design Selection

VOUGHT CORPORATION
an LTV company
dallas

Objective

To Describe the Application of Vought's ASAP/CFEM Methodology to Computer-Aided Aircraft Design. Particular Areas of Interest Pertain to:

- Use of Campaign Force Effectiveness Factor as Measure for Aircraft Design Optimization
- CFEMs Ability to Evaluate the Campaign Force Effectiveness of Point Design Aircraft
- Sensitivity of Campaign Force Effectiveness To Force Attrition

ASAP/CFEM Methodology

- ASAP is an aircraft synthesis program, which integrates various engineering disciplines and their interactions into effective aircraft designs. It not only can "size" an aircraft based on operational and mission requirements, but can also search for the "best" configuration in reference to the Merit Function.

VOUGHT

ASAP/CFEM Methodology

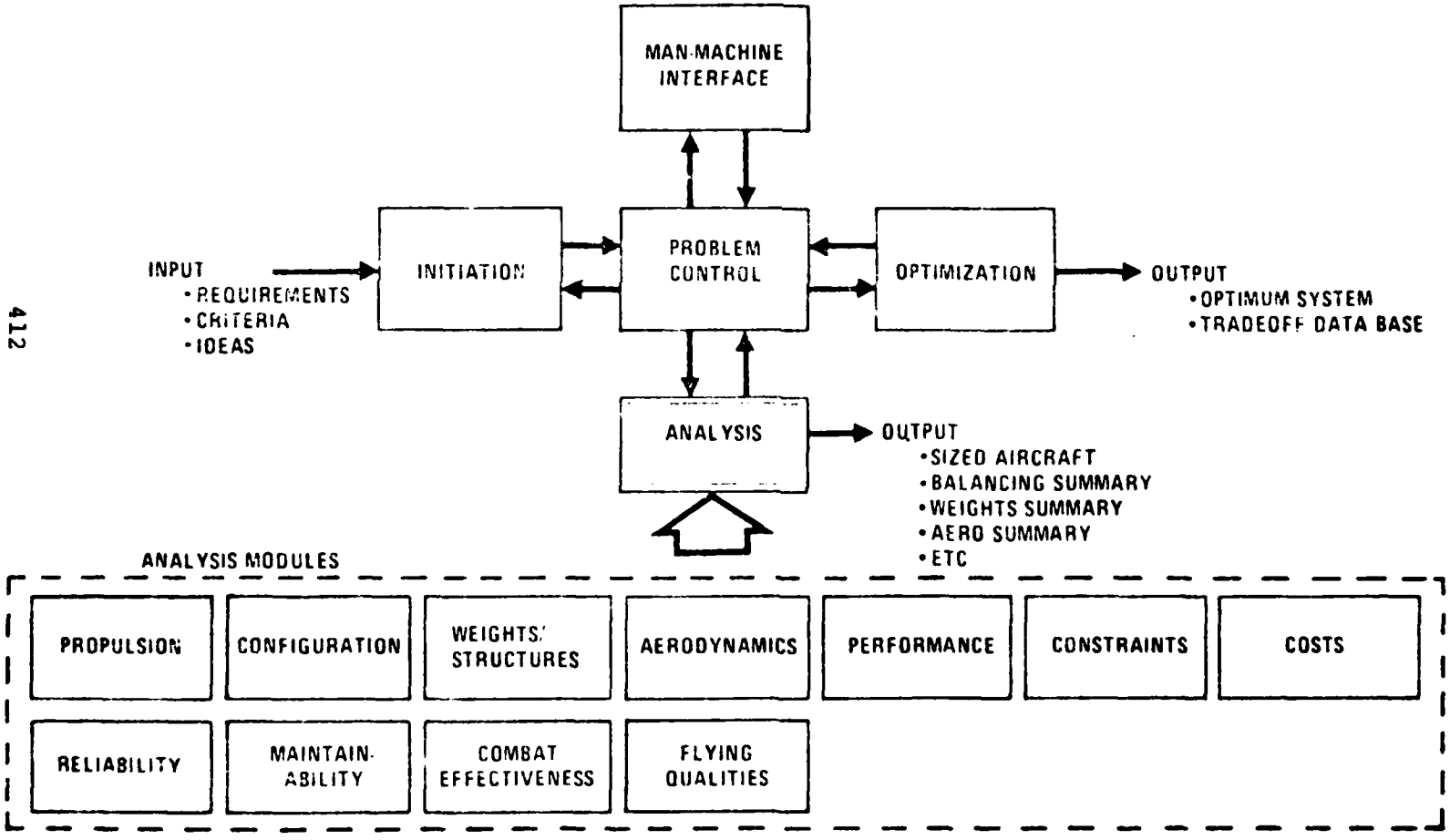
- CFEM Is a Bookkeeping Model. It Evaluates the Campaign Force Effectiveness of Combat Aircraft — Based on the Aircraft's:
  - Sortie Generation Capability
  - Target Kill Effectiveness

The Sortie Generation Parameter Is Sensitive to:

- Aircraft Survivability
- Combat Damage
- Unscheduled Maintenance
- Reliability
- Repair Downtime

VOUGHT

AIRCRAFT SYNTHESIS ANALYSIS PROGRAM (ASAP)



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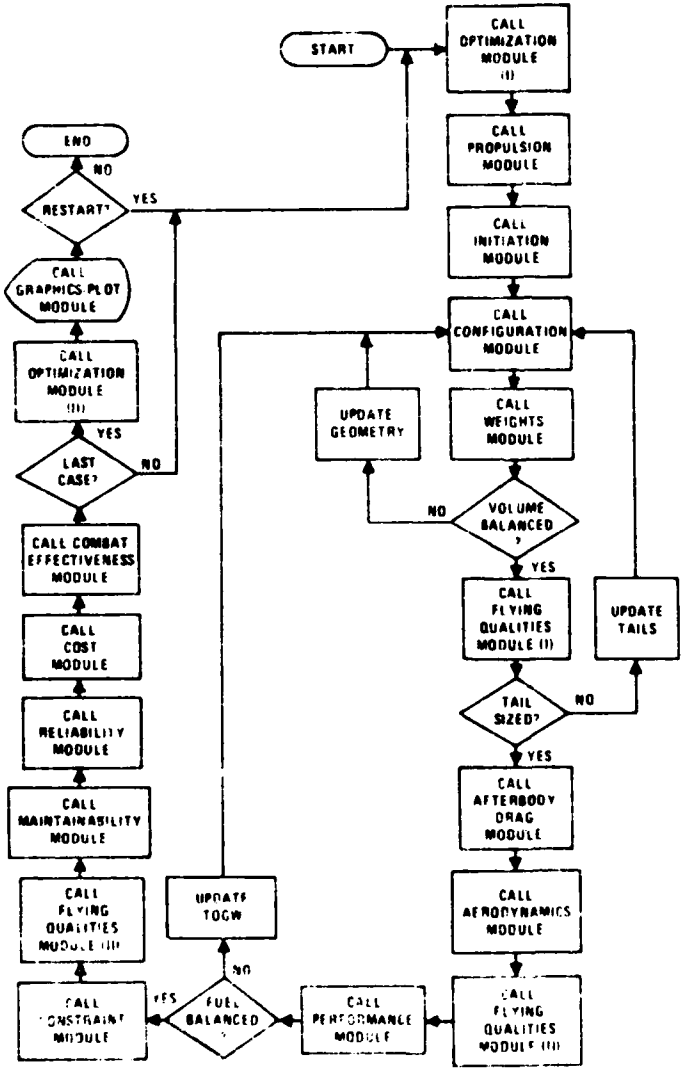
ASAP Logic Flow Diagram



INITIATION MODULE
- IDENTIFY NOMINAL AIRCRAFT CHARACTERISTICS
- DERIVE LAYOUT VIA ICG
- SPECIFY DESIGN SPACE

OPTIMIZATION MODULE
- (I) SELECT RESPONSE POINTS
- (III) ACTIVATES SEARCH PROCEDURE(S)

PROPULSION MODULE
- COMPUTE THRUST, FUEL FLOW AS FN(ALT, M_0, Pg)

CONFIGURATION MODULE
- COMPUTE AIRCRAFT GEOMETRY

WEIGHTS MODULE
- COMPUTE FUEL AVAILABLE AT A GIVEN TOGW

FLYING QUALITIES MODULE
- (I) COMPUTE AERO DATA
  - COMPUTE AEROELASTIC EFFECTS
  - SIZE AND LOCATE SURFACE
- (III) TRIM AERO DATA
- (IIII) COMPUTE FLYING QUALITIES OPERATIONAL CONSTRAINTS

AFTERBODY DRAG
- COMPUTE THROTTLE DEPENDENT DRAG

AERODYNAMICS MODULE
- COMPUTE CRUISE CONFIGURATION LIFT AND DRAG

PERFORMANCE MODULE
- COMPUTE FUEL REQUIRED AT A GIVEN TOGW

CONSTRAINT MODULE
- COMPUTE PERFORMANCE OPERATIONAL CONSTRAINTS

MAINTAINABILITY MODULE
- COMPUTE AIRCRAFT AVAILABILITY, MAINTENANCE MAN HOURS PER FLIGHT HOUR

RELIABILITY MODULE
- COMPUTE PROBABILITY OF FAILURE, MISSION ABORT GIVEN FAILURE, AND AIRCRAFT LOSS GIVEN FAILURE

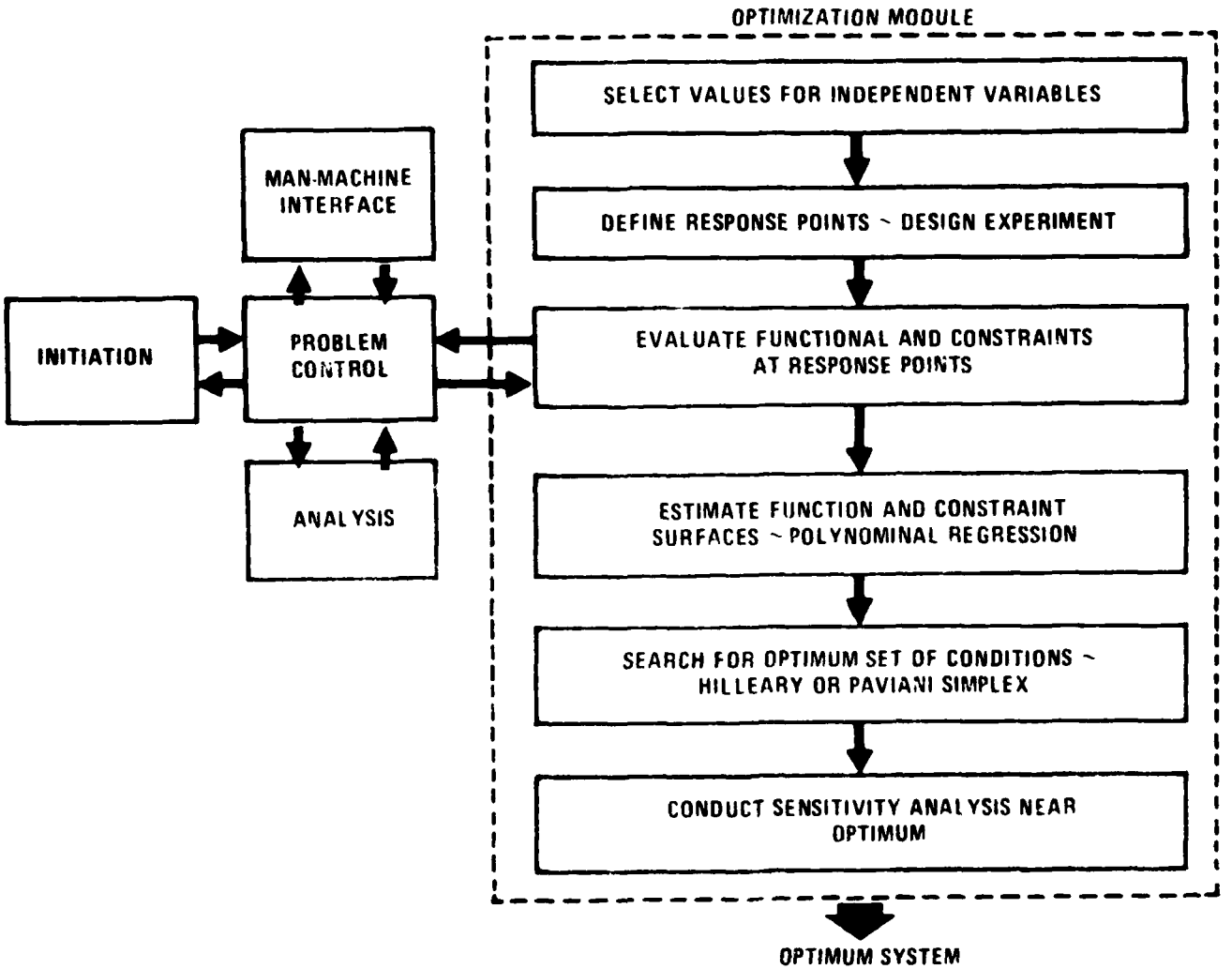
COST MODULE
- COMPUTE AIRCRAFT COST

COMBAT EFFECTIVENESS MODULE
- COMPUTE TARGETS KILLED, AIRCRAFT LOST, AIRCRAFT IN REPAIR, AND AIRCRAFT AVAILABLE FOR NEXT DAY

GRAPHICS/PLOT MODULE
- DISPLAY RESULTS
- SIZE AIRCRAFT

VOUGHT

KEY ELEMENTS OF THE OPTIMIZATION PROCESS



1. SELECTION OF INDEPENDENT VARIABLES

VOUGHT

VARIABLES AVAILABLE IN ASAP

WING PLANFORM VARIABLES

- AREA (FIXED OR CONSTANT WING LOADING)
- ASPECT RATIO
- THICKNESS RATIO
- TAPER RATIO
- SWEEP (QUARTER CHORD OR LEADING EDGE)

ENGINE VARIABLES

- ENGINE SCALE FACTOR (FIXED OR CONSTANT THRUST-TO-WEIGHT RATIO)
- BYPASS RATIO
- TURBINE INLET TEMPERATURE
- OVERALL PRESSURE RATIO
- SCHEDULING PARAMETER

MISSION VARIABLES

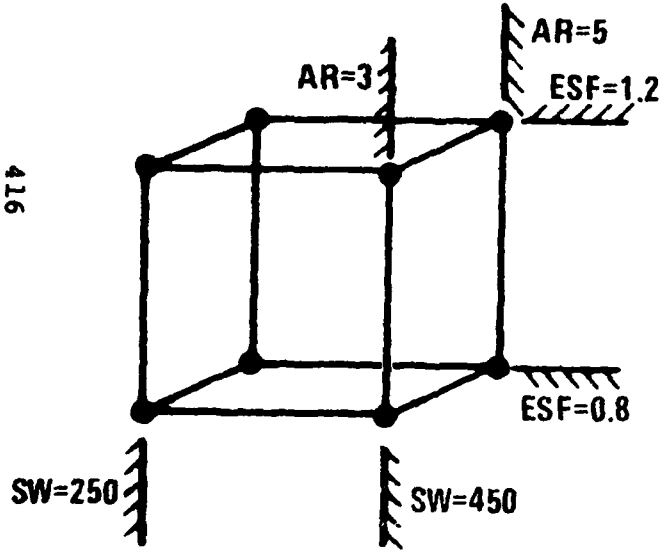
- PENETRATION DISTANCE
- PENETRATION ALTITUDE
- PENETRATION MACH NUMBER
- DISTANCE TO FEBA
- ORDNANCE WEIGHT
- NUMBER OF BOMBS
- LOITER TIME

VOUGHT

2. DEFINE RESPONSE POINTS

DESIGN SPACE DEFINITION

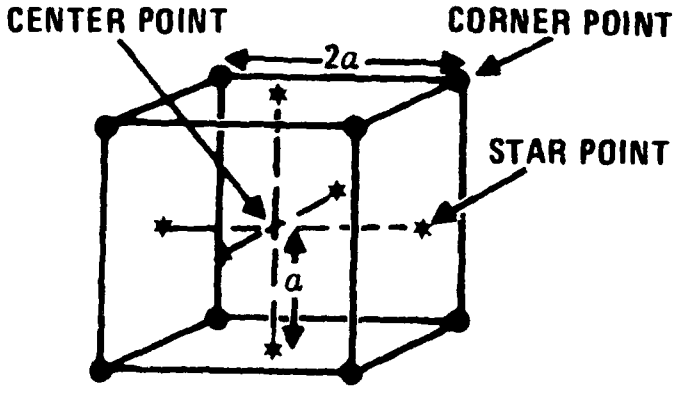
PARAMETRIC APPROACH



COMBINATIONS REQUIRED = 3^n
WHERE:

n = NUMBER OF INDEPENDENT VARIABLES

OPTIMIZATION APPROACH



MODIFIED COMPOSITE DESIGN

COMBINATIONS REQUIRED = $2^n + 2n + 1$

P6-928(1)-9

2. DEFINE RESPONSE POINTS

RESPONSE POINT REQUIREMENTS

NUMBER OF INDEPENDENT VARIABLES – n	PARAMETRIC/ FULL FACTORIAL 3^n	MODIFIED CENTRAL COMPOSITE DESIGN $2^n + 2n + 1$	LATIN SQUARE DESIGN $(n + 1)^2$	D-OPTIMUM DESIGN $\frac{(n+1)(n+2)}{2} + 1$
2	9	9	9	7
3	27	15	16	11
4	81	25	25	16
5	243	43	36	22
6	729	77	49	29
7	2,187	143	64	37
8	6,561	273	81	46
9	19,683	531	100	56
10	59,049	1,045	121	67
11	177,147	2,071	144	79
12	531,441	4,121	169	92
13	1,594,323	8,219	196	106
↓				
20	3,486,784,401	1,048,617	441	232

4. ESTIMATE FUNCTION AND CONSTRAINT SURFACES

SECOND ORDER STEP-UP, STEP-DOWN REGRESSION

TO THE EQUATION:

$$Y = a_0 + a_1x_1 + a_2x_2 + -- + a_nx_n + a_{11}x_1^2 + a_{12}x_1x_2$$

$$+ --- + a_{1n}x_1x_n + a_{22}x_2^2 + a_{23}x_2x_3 + -- + a_{2n}x_2x_n$$

$$+ --- + a_{nn}x_n^2$$

TERMS ARE ADDED/DELETED TO MAXIMIZE CORRELATION

5. SEARCH FOR OPTIMUM

VOUGHT

SEARCH TECHNIQUES

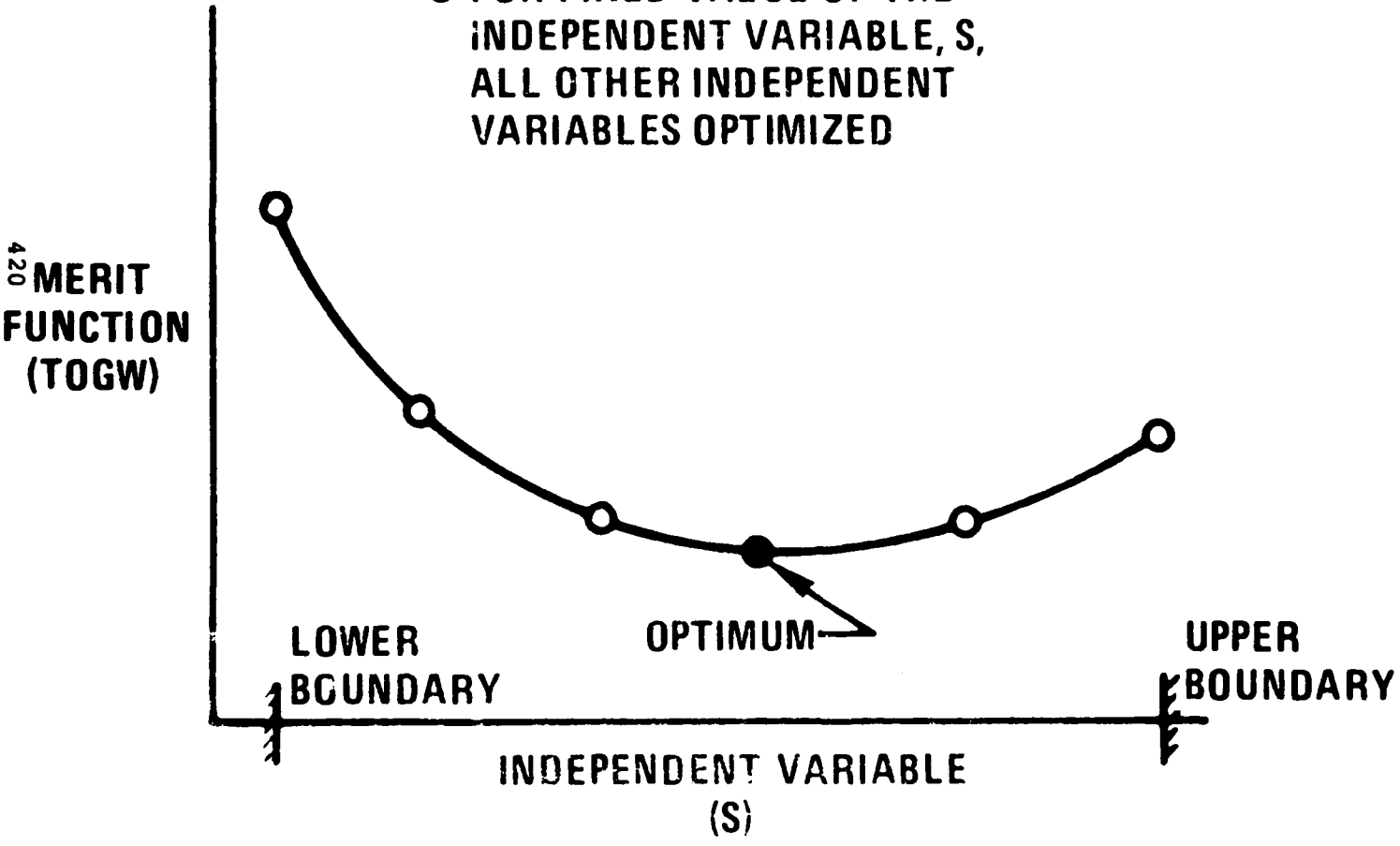
- HILLEARY – CONVENTIONAL GRADIENT (TANGENT PLANE) SEARCH
- SIMPLEX – GEOMETRIC SEARCH UTILIZING A FLEXIBLE n + 1 SIDED POLYGON IN n-SPACE

6. CONDUCT SENSITIVITY ANALYSIS

VOUGHT

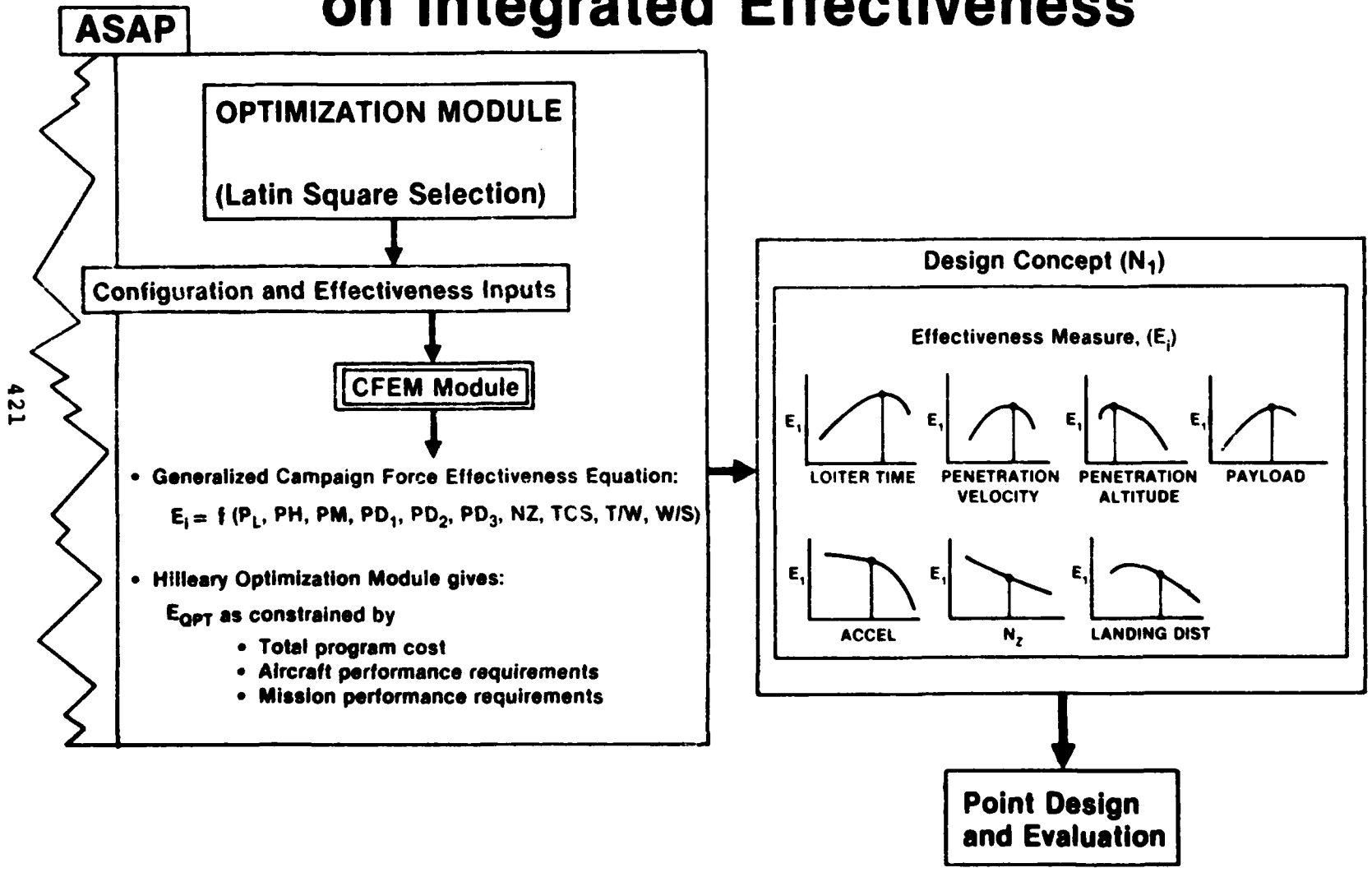
BUCKET PLOT SENSITIVITY

- FOR FIXED VALUE OF THE INDEPENDENT VARIABLE, S, ALL OTHER INDEPENDENT VARIABLES OPTIMIZED



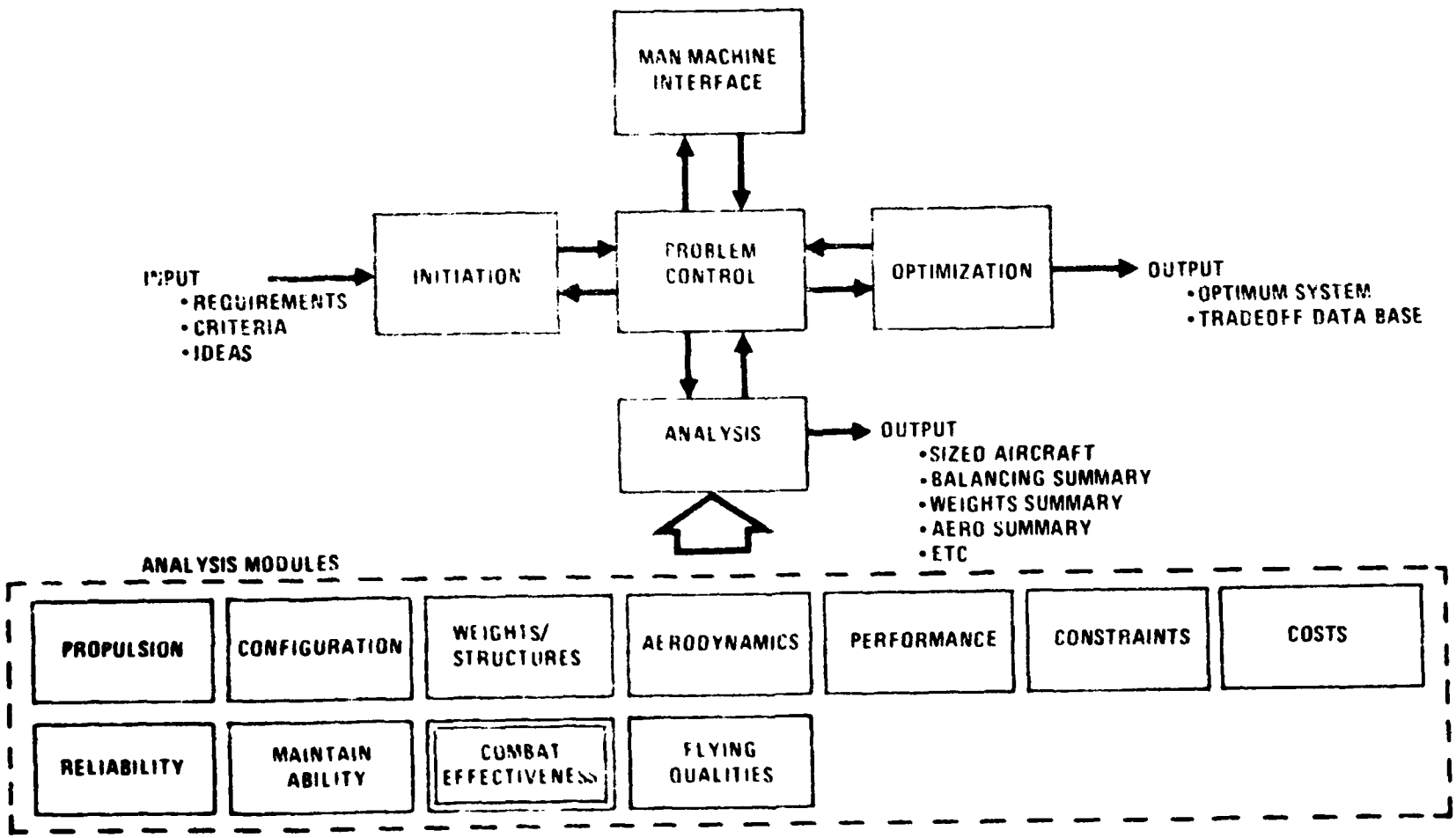
VOUGHT

Design Concept Optimization Based on Integrated Effectiveness



VOUGHT

AIRCRAFT SYNTHESIS ANALYSIS PROGRAM (ASAP)



CFEM

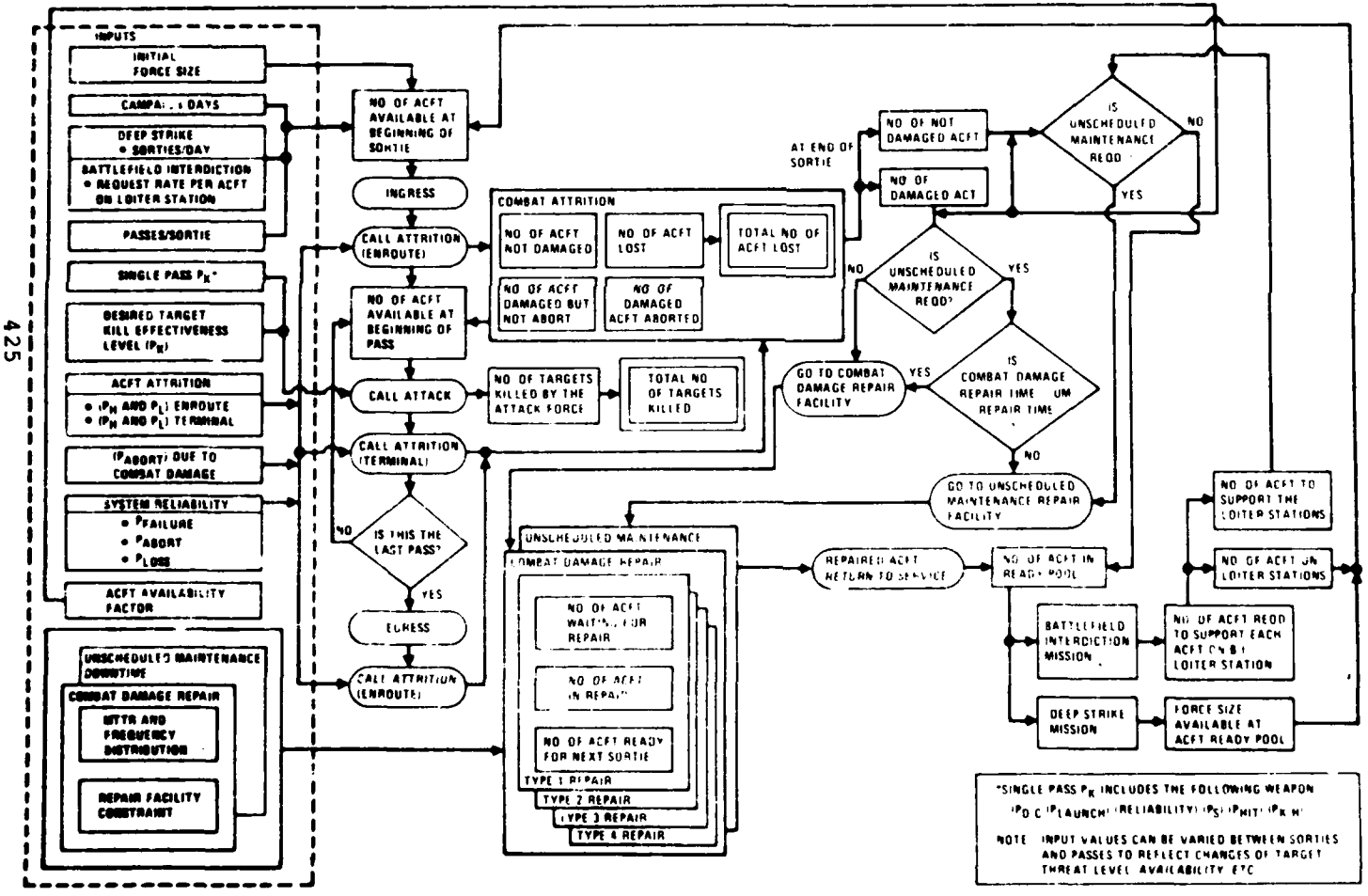
- Evaluates the sortie generation capability of point design aircraft based on force attrition
- Examines the target kill effectiveness per sortie
- Computes the campaign force effectiveness in terms of percent targets killed in a given number of campaign days with a force size of fixed procurement cost

Force Attrition Is Sensitive to:

- Threat Scenario
- Mission Performance:
  - Penetration Distance over the Threat Area
  - Penetration Speed and Altitude
  - Weapon Delivery Standoff Distance
  - Defense Suppression
- Aircraft Vulnerability:
  - Probability of Hit by the Defense
  - Probability of Kill Given a Hit
  - Probability of Mission Abort Given a Hit
- Repair Capability:
  - Repair Downtime
  - Repair Facility Capacity

VOUGHT

COMBAT EFFECTIVENESS MODULE LOGIC FLOW DIAGRAM



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COMBAT EFFECTIVENESS MODULE DATA REQUIREMENTS

VOUGHT

DATA REQUIRED	SOURCE
INITIAL FORCE SIZE	COST MODULE
NO. OF CAMPAIGN DAYS	INPUT
LENGTH OF OPERATIONAL DAY	INPUT
NO. OF SORTIES PER DAY	INPUT
TARGET DISTRIBUTION	INPUT TABLE
WEATHER DISTRIBUTION	INPUT TABLE
DESIRED TARGET KILL EFFECTIVENESS LEVEL, P_K	INPUT
ORDNANCE LOAD	PROBLEM CONTROL MODULE
PAYLOAD vs. RADIUS OR TOS	PERFORMANCE MODULE
AIRCRAFT ATTRITION	
• P_S SURFACE-TO-AIR ENROUTE*	INPUT TABLE FOR EACH THREAT
• P_S AIR-TO-AIR ENROUTE*	INPUT TABLE
• P_S SURFACE-TO-AIR TERMINAL*	INPUT TABLE
• THREAT DENSITY	INPUT
• THREAT RANGE	INPUT
• P_{ABORT} DUE TO COMBAT DAMAGE	INPUT
SYSTEM RELIABILITY	
• $P_{FAILURE}$	RELIABILITY MODULE
• P_{ABORT}	RELIABILITY MODULE
• P_{LOSS}	RELIABILITY MODULE
AIRCRAFT AVAILABILITY FACTOR	MAINTAINABILITY MODULE
COMBAT DAMAGE REPAIR	
• TIME DISTRIBUTION	INPUT TABLE
• FACILITY CONSTRAINT	INPUT
UNSCHEDULED MAINTENANCE REPAIR	
• TIME DISTRIBUTION	INPUT TABLE
• FACILITY CONSTRAINT	INPUT

*(ONE-ON-ONE ENGAGEMENT)

VOUGHT

COMBAT EFFECTIVENESS MODULE OUTPUTS*

- NO. OF AIRCRAFT AVAILABLE AT BEGINNING OF EACH SORTIE (FOR STRIKE MISSION) OR AT BEGINNING OF EACH TIME-ON-STATION CYCLE (CAS/BI MISSION)
- NO. OF AIRCRAFT AVAILABLE TO CARRY OUT THE ATTACK
- AMOUNT OF ORDNANCE DELIVERED
- NO. OF TARGETS KILLED
- NO. OF AIRCRAFT LOST
- NO. OF WEAPONS LOST
- NO. OF AIRCRAFT DAMAGED
- NO. OF AIRCRAFT IN REPAIR (COMBAT DAMAGE)
- NO. OF AIRCRAFT IN REPAIR (UNSCHEDULED MAINTENANCE)
- NO. OF AIRCRAFT WAITING FOR REPAIR (COMBAT DAMAGE)
- NO. OF AIRCRAFT WAITING FOR REPAIR (UNSCHEDULED MAINTENANCE)
- TOTAL NUMBER OF PASSES PERFORMED (OR TOTAL NUMBER OF REQUESTS SATISFIED)

*(AS FUNCTION OF CAMPAIGN DAYS)

VOUGHT

ASAP/CFEM Data Flow

(1) Enroute Survival

(A) Against Surface-to-Air Defense:

$$\left[(P_s)_{SA}\right]_i = f(V, h, n_g, DSE, ...)$$

- V .... Penetration Velocity
- h .... Penetration Altitude
- n_g .... Maneuver 'g' Capability
- DSE .... Defense Suppression Effectiveness

(B) Against Air-to-Air Defense:

$$\left[(P_s)_{AA}\right] = f(V, h, T/W, W/S, TWC, ...)$$

- T/W .... Thrust-to-Weight Ratio
- W/S .... Wing Loading
- TWC .... Threat Warning Capability

VOUGHT

ASAP/CFEM Data Flow (cont)

(2) TERMINAL SURVIVAL

- Against Surface-to-Air Defense

$$\left[(P_S)_T\right]_i = f(V, h, n_g, DSE, D_s, ...)$$

D_s .... Standoff Distance

(3) FORCE ATTRITION

- Expected No. of Aircraft Lost
- Expected No. of Aircraft Damaged
- Force Size Available for Next Mission

VOUGHT

ASAP/CFEM Data Flow (cont)

(4) TARGET KILL EFFECTIVENESS

- Expected No. of i-Type Targets Killed per Pass:

$$\left[(T_K)_p\right]_i = f(R, W_{PL}, D_S, P_{d/A}, CEP, R_L, ...)$$

R	....	Mission Radius
W_{PL}	....	Payload Capability
D_S	....	Standoff Distance
$P_{d/A}$	....	Target Detection and Acquisition Probability
CEP	....	Weapon Delivery Accuracy
R_L	....	Weapon Lethal Radius

(5) CAMPAIGN FORCE EFFECTIVENESS MEASURE

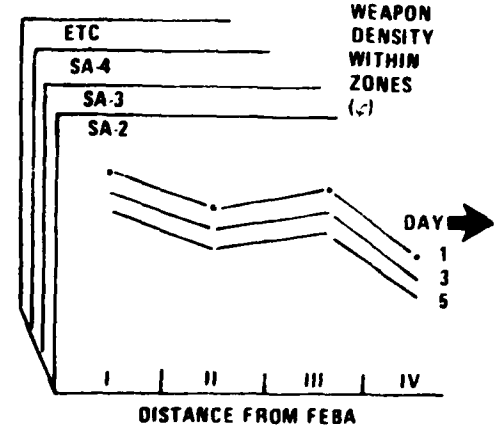
(A) Force Size Required To Kill Given Targets in Specified No. of Campaign Days

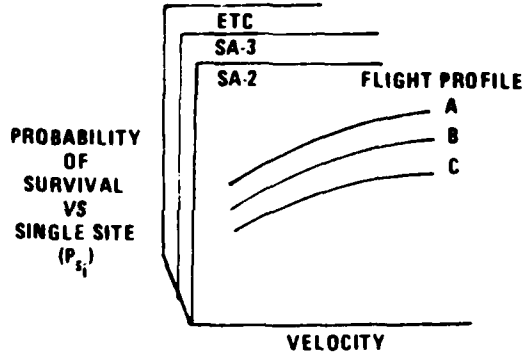
(B) Percent Targets Killed by a Given Force Size at Equal Program Cost and Campaign Days

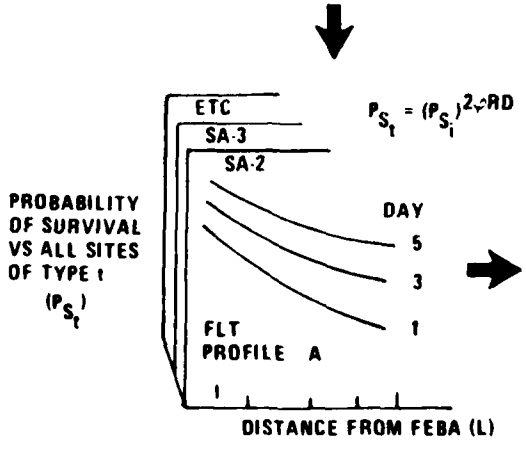
VOUGHT

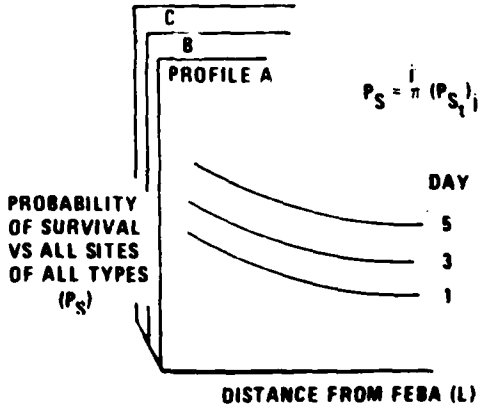
SCENARIO DATA APPLICATION (ENROUTE SURVIVABILITY)

SURFACE TO AIR WEAPONS	NOS IN ZONE			
	I	II	III	IV
SA-2	n_{11}	n_{12}	n_{13}	n_{14}
SA-3	n_{21}	n_{22}	n_{23}	n_{24}
SA-4	n_{31}	n_{32}	n_{33}	n_{34}
SA-6	n_{41}	n_{42}	n_{43}	n_{44}
ETC				





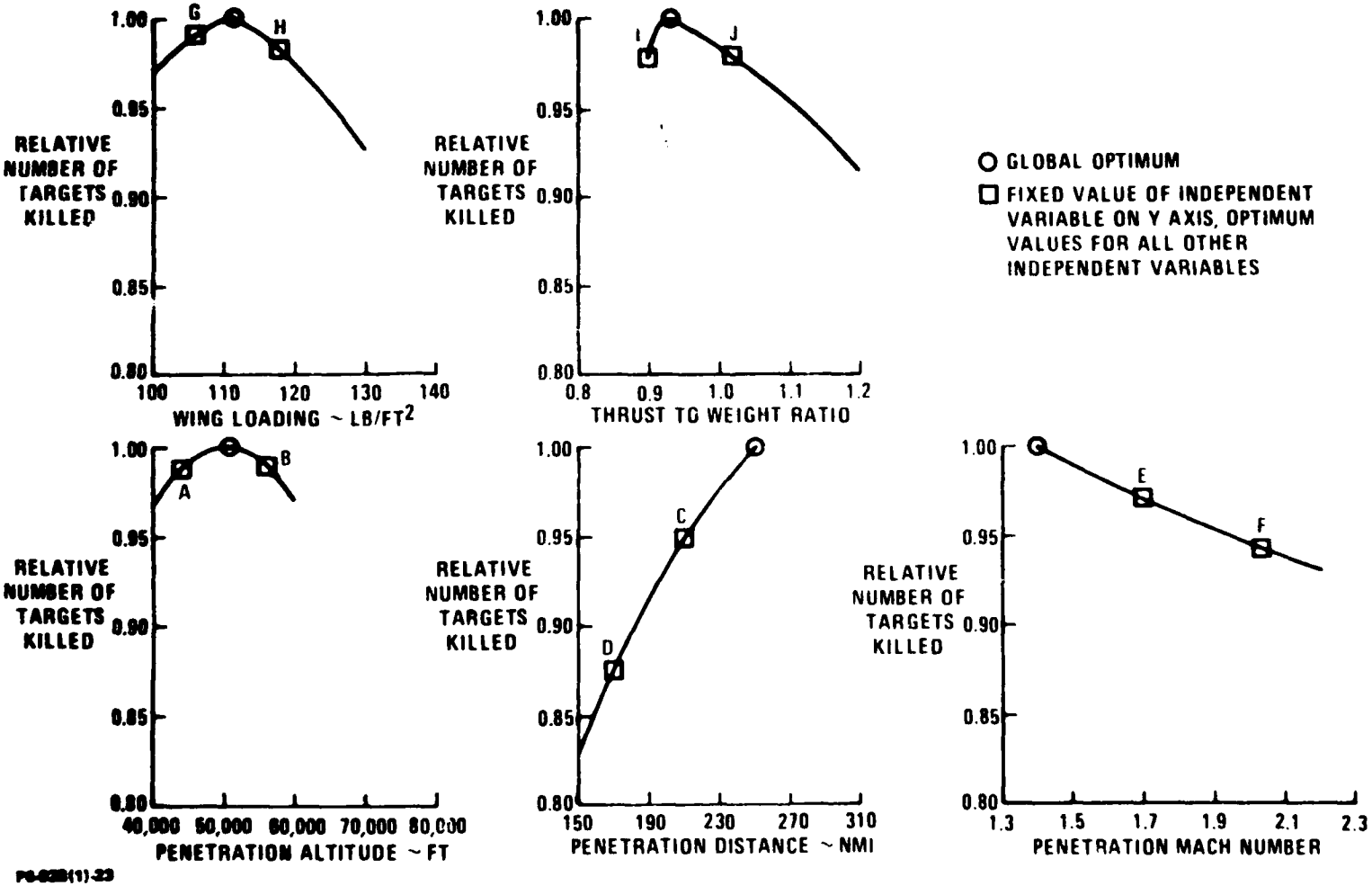




NOTES:

- σ IS MODIFIED BY AN AVAILABILITY FACTOR RELATED TO OPERATIONAL CONCEPT, i.e., RE % SHUTDOWN OR MOVING
- NO. OF SITES DECREASES WITH TIME DUE TO ATTRITION, LOGISTICS, ETC. TYPICAL ASSUMPTION: ONLY 50% OF SURVIVING SITES OF PREVIOUS DAY SURVIVE PER DAY.

LONG-RANGE STRIKE SENSITIVITY DATA



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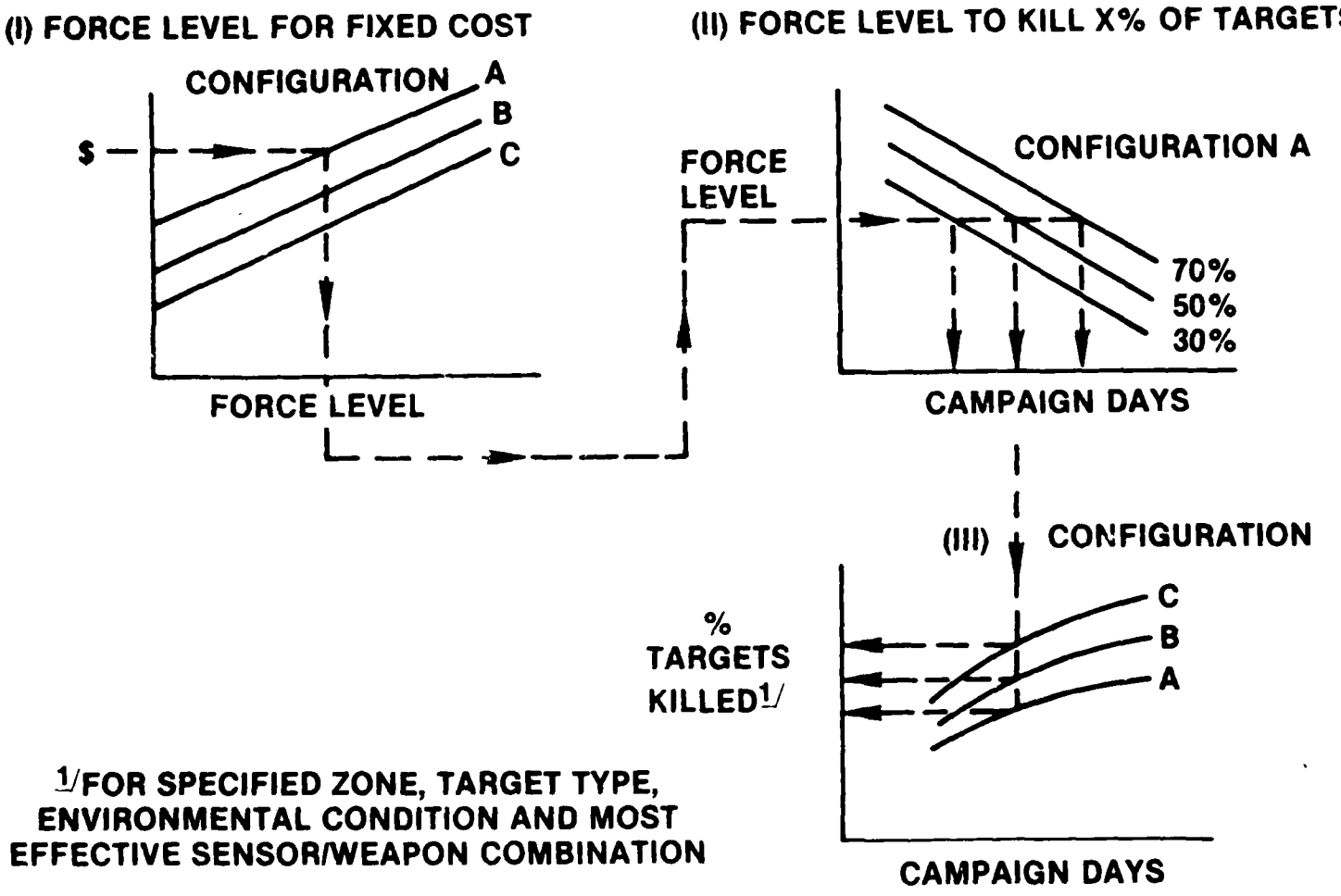
VOUGHT

Cost Effectiveness Comparisons

Effectiveness/Fixed Cost



1/FOR SPECIFIED ZONE, TARGET TYPE, ENVIRONMENTAL CONDITION AND MOST EFFECTIVE SENSOR/WEAPON COMBINATION

P1-1157 3

VOUGHT

WHAT IS THE MOST EFFECTIVE AIRCRAFT?

	CONFIGURATION										
	A	B	C	D	E	F	G	H	I	J	OPTIMUM
PENETRATION ALTITUDE ~ FT	[44,000]	[56,000]	48,140	45,687	54,050	57,540	50,680	50,370	50,840	50,870	50,800
PENETRATION DISTANCE ~ NMI	250	250	[210]	[170]	250	250	250	250	250	250	250
PENETRATION MACH NUMBER	1.4	1.4	1.4	1.4	[1.72]	[2.04]	1.4	1.4	1.64	1.4	1.40
WING LOADING ~ LB/FT^2	110.0	111.5	112.7	113.9	110.2	111.5	[106]	[118]	110.0	118.7	111.4
THRUST LOADING	0.919	0.937	0.949	0.967	0.900	0.900	0.932	1.011	[0.900]	[1.02]	0.931
NUMBER OF TARGETS KILLED	0.987	0.989	0.948	0.874	0.969	0.942	0.991	0.983	0.976	0.978	1.000
NUMBER OF AIRCRAFT LOST	1.003	0.998	0.933	0.923	0.815	0.677	0.992	0.976	0.862	0.974	1.000
NUMBER OF AIRCRAFT IN REPAIR	0.990	0.999	0.931	0.922	0.998	0.998	0.992	0.987	0.996	0.986	1.000
NUMBER OF AIRCRAFT NEXT DAY	0.982	0.998	1.135	1.192	1.007	1.016	0.994	0.983	1.000	0.983	1.000
TAKEOFF GROSS WEIGHT	1.040	1.004	0.953	0.903	1.119	1.221	1.007	1.012	1.101	1.012	1.000
FLYAWAY COST	1.013	1.004	0.982	0.963	1.042	1.080	1.009	1.010	1.035	1.012	1.000
FORCE SIZE (UE)	0.987	0.998	1.019	1.039	0.960	0.921	0.993	0.984	0.967	0.982	1.000
LANDING GROUND ROLL	0.996	1.000	1.010	1.020	0.988	0.999	0.959	1.053	0.988	1.058	1.000
EQUILIBRIUM N_Z – 30K, MN = 0.9	1.0	1.0	1.0	1.0	1.0	1.0	1.031	1.0	1.0	1.0	*1.000
ACCELERATION TIME – 0.85 TO 1.6, 30K	1.0	0.998	1.0	1.0	0.988	0.929	1.0	0.840	1.0	0.826	*1.000

[ ] HELD CONSTANT

* SIZING CRITERIA

Conclusions

- Mission performance effectiveness is highly sensitive not only to aircraft survivability, but also to combat damage, unscheduled maintenance, reliability, and repair downtime. Consequently, their contributions would have to be considered in the design selection process. CFEM can be used in performing such task.

- ASAP/CFEM is an effective computer-aided design tool. It has been applied to many of Vought's aircraft programs.

AIRCRAFT DESIGN FOR SURVIVABILITY AND VULNERABILITY

Jerry Wallick
Chairman, JTCG/AS
Survivability Assessment Subgroup

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NOTE: Narrative numbers refer to circled vugraph numbers (lower right corner)

1. I will be presenting a two part briefing on the procedures used in the Air Force, Aeronautical Systems Division to design aircraft for survivability. Part I addresses current procedures for specifying survivability/vulnerability (S/V) requirements, while Part II is a summary presentation of an initiative to revise our current procedures and make specifications tailorable at the system level for S/V.

2. In Part I, I will overview current procedures and give some examples on how the Air Force requirements for S/V, both nuclear and non-nuclear, are arrived at and specified.

3. AFR 80-38 is the regulation designating responsibilities within the Air Force for implementing the survivability program, both technology development and system application. The regulation outlines what must be done rather than how to do it. For the most part, the Air Force Systems Command and the subordinte Acquisition Division (Aeronautical Systems Division for aircraft) then implement S/V programs on specific systems to assure that requirements are established and met.

4. AFR 80-38 defines the buzz words as shown here. I would point out that a major problem for S/V engineers when dealing with non-S/V discipline oriented engineers and managers is the distinction between survivability and vulnerability. The best way to make this distinction is to keep in mind that vulnerability is a subset of survivability, not the inverse probability. System survivability must consider vulnerability as well as characteristics associated with detectability, tactics, performance (speed and maneuverability), and countermeasures (active and passive).

5. Within the Air Force Systems Command the Weapons Laboratory is designated as the lead laboratory for nuclear and laser survivability technology development. This viewgraph lists the AFWL responsibilities in support of this technology development.

6. This viewgraph summarizes types of threats and nuclear threat kill mechanisms that form the basis of nuclear survivability requirements. Generally, nuclear requirements reduce to specification of hardness levels against the listed threat mechanisms. Based on postulated threats, missions of the system, and availability of technology, the S/V engineer establishes hardness requirements which represent a balance among the various threat mechanisms.

7. Moving on to non-nuclear S/V considerations, this viewgraph depicts a simplification of the problem we face. However, this is precisely the procedure found in captured North Vietnamese foot solider manuals defining how to shoot down U.S. aircraft in Southeast Asia.

8. This is the result of following the manual.

9. The Flight Dynamics Laboratory is designated the Air Force Systems Command lead laboratory for non-nuclear S/V technology development. This viewgraph outlines the AFWAL/FDL responsibilities in support of this technology development.

10. Types of threats and nonnuclear threat kill mechanisms, which are considered in establisning non-nuclear survivability requirements, are summarized. However, since non-nuclear threat effects are more point oriented (as compared to area coverage of nuclear weapons), specification of hardness requirements is not sufficient to adequately define system survivability except in the rare case where mission requirements are such that detection, tracking, and guidance by the threat are practically certain. The examples of current requirements, shown later, are for a system that must fly into the threat like this. The purpose of Part II of my presentation is to outline our apporach to addressing this problem.

11 & 12. These two viewgraphs show the AFWAL/FDL gunfire test facility at Wright-Patterson AFB, Ohio. In this facility it is possible to test full-scale sections of aircraft or missiles to impact by single fragments, multiple fragments, armor piercing projectiles, and high explosive projectiles up through 23 mm, under airflow conditions up to about 450 knots.

13. The Combat Data Information Center (CDIC) is a contractor-operated repository for non-nuclear combat data. CDIC is a DOD facility currently funded jointly by the JTCG/AS and JTCG/ME. A more detailed description of the CDIC can be found in the brochure handed out at the Workshop registration table. If you did not get one at

registration, the Air Force manager for CDIC is Mr. Gary Streets, AFWAL/ FIES, WPAFB, Ohio 45433. The telephone number is (513) 255-4840 or autovon 785-4840.

14, 15, & 16. These viewgraphs are a series of gun camera photographs showing an F-4 aircraft encountering an SA-2 in Southeast Asia. This is an example of one type data available at CDIC.

17. Shown here are the elements of a typical non-nuclear S/V program for a system. The intent is to show how threat, operational parameters, system vulnerability, and survivability requirements are iteratively considered, analyzed, and tested to arrive at a "survivable system." Development of appropriate or adequate survivability requirements can be seen as a complex and, at times, painful iteration of many factors which may become very subjective. As the discipline matures it is hoped that some of this subjectivity will be removed. Recent developments in methodology, data bases, and test procedures are fundamental to correcting this problem, and successful implementation of the specifications is discussed later in Part II.

18. This viewgraph outlines the current procedure for defining nuclear survivability requirements. You will note here that the Air Force uses the Nuclear Criteria Group, a general officer level group at Air Staff level, to define free-field nuclear environments which serve as the basis for system requirements. As you will recall, specification of nuclear S/V requirements has historically taken the form of designing to hardness levels. Although not a trivial task for the designer, specification of the requirement has been somewhat easier and more quantifiable than for non-nuclear requirements.

19 & 20. These viewgraphs are a kind of checklist for parameters and relationships for factors to consider in establishing requirements for non-nuclear S/V system and subsystem specifications. As might be expected from previous comments on the complexity of defining non-nuclear requirements, the specifications most applicable to aircraft design are those addressing signatures, performance and kill probability (i.e., reducing the probability of kill given a hit).

21. Shown here are A-10 design requirements for nonnuclear survivability and a summary of demonstrated hardness. Shaded areas labeled "demonstrated" have been subjected to testing at the threat level specified or have been analytically evaluated to assure that those subsystems have

indeed been designed to withstand a single impact from that threat.

22 & 23. These viewgraphs outline current analytical methods used at ASD to assess aircraft survivability and vulnerability and the considerations included. As can be seen, current methods use rather detailed level of design information. This is one area where I feel a considerable amount of work needs to be done in order for survivability to be fully integrated into computer-aided design. Methods, data, and S/V engineering should interface with conceptual and preliminary designers to effectively make S/V a "cradle to grave" system engineering discipline.

24. In Part II of my presentation, I would like to outline a project we are undertaking at ASD, Deputy for Engineering, which has the potential to correct some of the problems we have heard defined at this workshop by industry regarding inadequacy of definition of specific S/V requirements by services. This project, although being worked by the Air Force, has been briefed at DOD level and the eventual intent is to put the documentation into a MIL-STD for full coordination.

25. The total ASD initiative encompasses the entire system specification writing effort, of which the S/V document, Aeronautical Systems Mission Completion in a Combat Environment, is one of approximately 150 documents, which are intended to replace over 9100 specifications and standards now in use by the Air Force in writing and specifying system requirements. Each separate discipline will be writing a MIL-PRIME document, in the form of a specification or standard, stating requirements (with blanks to be filled in as the specification is tailored). It will be accompanied by a MIL-HANDBOOK which is to provide technical back-up, rationale, and lessons learned for use by the engineers in tailoring the specification.

26. This is a list of the concerns addressed in the draft MIL-STD we have developed for S/V.

27. The operational needs are addressed as primary and secondary mission requirements associated with initial day and subsequent days of the war. In addition, there are provisions for specifying post-combat availability, such as battle damage repair time, of several time dependent categories.

28, 29, & 30. These viewgraphs are excerpts of some of the actual requirements of section 3 and validation procedures of section 4 from the draft MIL-STD.

31. Currently we have developed a draft of the MIL-STD which is in technical review by ASD. Mr. Dudley Ward (ASD/ENFTV) is identified as the primary engineer for the S/V MIL-STD and HANDBOOK. We are approximately 25 percent of the way through development of a draft HANDBOOK which is scheduled for completion in June 1981. Much of the information for the HANDBOOK is being derived from the current JTCG/AS S/V Handbook and from AFSC Design Handbook 2-7. In addition, other JTCG/AS and Defense nuclear documents are being used as resources.

32 & 33. These viewgraphs give an indication of how far we have come in the S/V area, particularly from the standpoint of fuel system arrangement and protection against non-nuclear threats. The DeHavilland 4 was known as the flying coffin. Ground troops were instructed to aim at the pilot to shoot it down. However, it was not too critical to hit the pilot since the fuel tank was right behind the pilot and as often as not, aircraft kill was caused by a fire or explosion of the hit fuel tank. As "contrasted to the advanced technology used in the F-4" where (again) the fuel tank was installed right against the Guy in Back, again the same problems existed. In the F-4 we had to resort to accepting the penalty of parasitic protection to achieve "acceptable" attrition rates for the aircraft when we went to war.

34. I feel we have had a good three days of interaction between S/V engineers and analysts and system designers this should set the stage for further formal efforts to integrate S/V design into the aircraft conceptual and preliminary design cycle. The total team running in the race can have extremely beneficial payoff as opposed to the brute force method we currently use for getting S/V into the system as an off-the-track (more precisely off-line) or after-the-fact fix-up of weapon systems.

AIRCRAFT DESIGN FOR SURVIVABILITY AND VULNERABILITY

PRESENTER:
JERRY WALLICK
AERONAUTICAL SYSTEMS DIVISION

PART I

CURRENT SYSTEMS

MANAGEMENT OF THE AIR FORCE SURVIVABILITY PROGRAM — AFR 80-38 . . .

INSURES THAT . . .

a. AIR FORCE SYSTEMS AND MISSION EQUIPMENT ARE CAPABLE OF SURVIVING THE EFFECTS OF A MAN-MADE HOSTILE ENVIRONMENT.

b. SURVIVABILITY IS FULLY CONSIDERED IN EACH USAF SYSTEM PROGRAM DURING THE ACQUISITION LIFE CYCLE.

c. SYSTEM SURVIVABILITY IS REEVALUATED THROUGHOUT THE ACQUISITION LIFE CYCLE OF EACH SYSTEM WHEN EITHER THE HOSTILE ENVIRONMENT, THE SYSTEM, OR THE MISSION IS ALTERED.

d. SYSTEM HARDNESS IS MAINTAINED THROUGHOUT THE ACQUISITION LIFE CYCLE OF EACH SYSTEM.

TERMINOLOGY

SURVIVABILITY—THE CAPABILITY OF A SYSTEM TO AVOID AND WITHSTAND A MAN-MADE HOSTILE ENVIRONMENT WITHOUT SUFFERING ABORTIVE IMPAIRMENT OF ITS ABILITY TO ACCOMPLISH ITS DESIGNATED MISSION

VULNERABILITY—THE CHARACTERISTICS OF A SYSTEM WHICH CAUSE IT TO SUFFER A FINITE DEGRADATION (INCAPABILITY TO PERFORM THE DESIGNATED MISSION) AS A RESULT OF HAVING BEEN SUBJECTED TO A CERTAIN LEVEL OF EFFECTS IN A MAN-MADE HOSTILE ENVIRONMENT.

HARDNESS—A MEASURE OF THE ABILITY OF A SYSTEM TO WITHSTAND EXPOSURE TO ONE OR MORE OF THE EFFECTS OF EITHER NUCLEAR OR NONNUCLEAR WEAPONS.

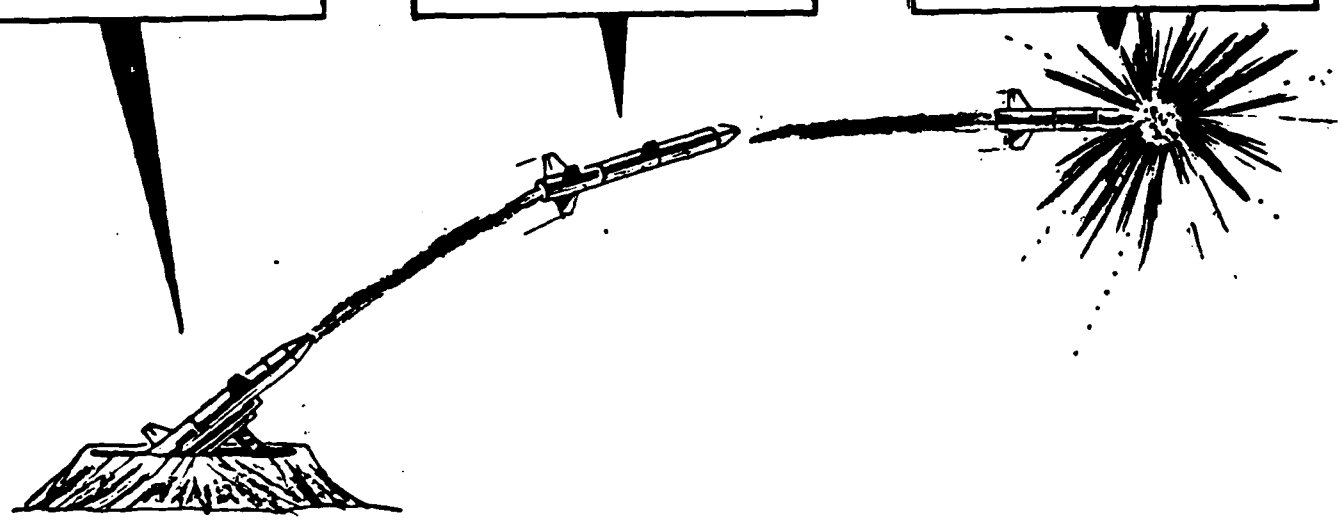
AIR FORCE WEAPONS LABORATORY

(NUCLEAR & LASER S/V)

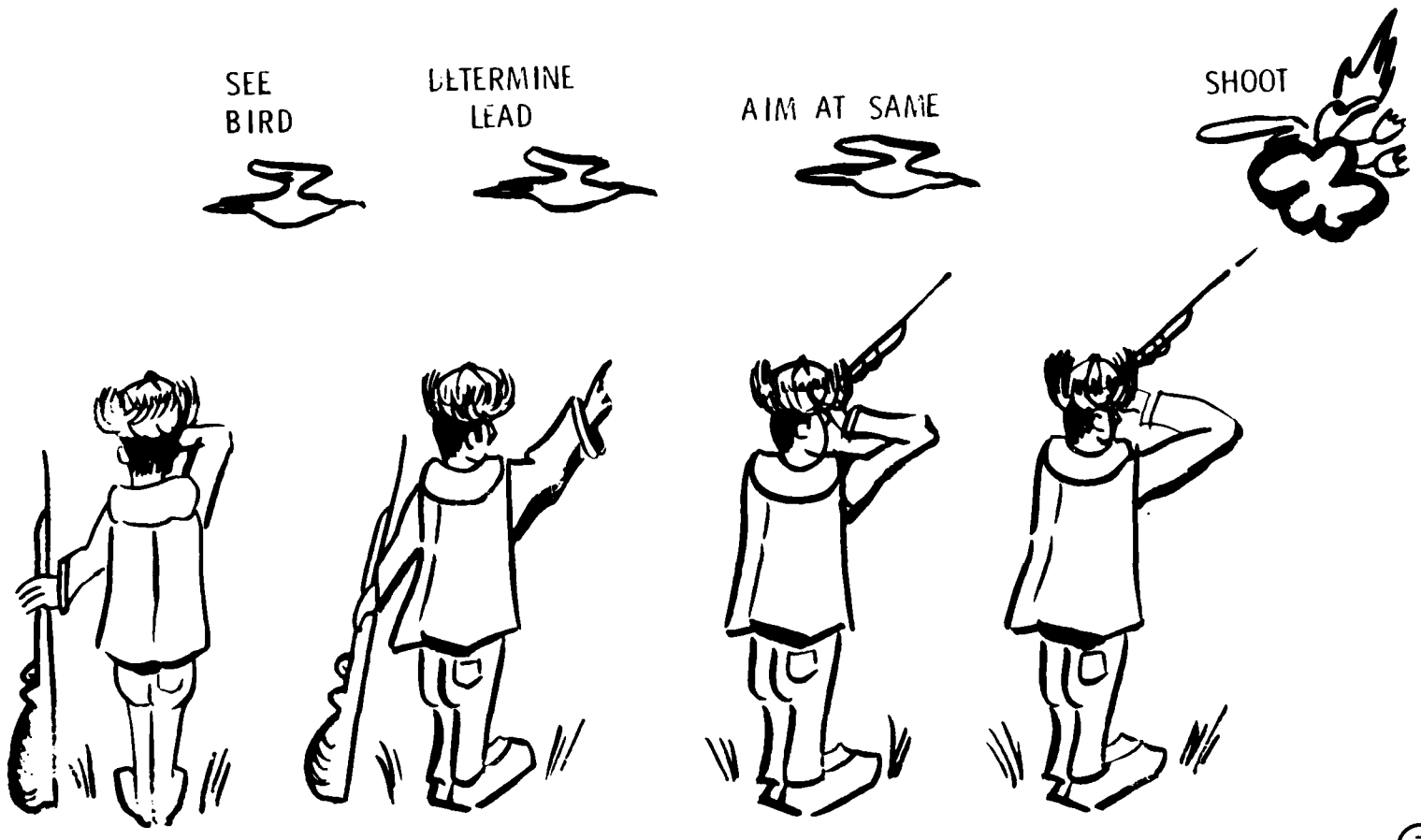
- NUCLEAR WEAPONS EFFECTS (NWE) PROGRAMS
- NWE TECHNOLOGY DATA BASE
- NUCLEAR ENVIRONMENT SIMULATION & TESTING
- NUCLEAR HARDNESS ASSESSMENT TECHNIQUES
- SIMILAR CAPABILITIES FOR LASER S/V TECHNOLOGY

NUCLEAR THREATS

GENERAL THREATS	WARHEAD DESCRIPTORS	THREAT MECHANISMS
• ICBM • SLBM • AAM • SAM	• Kilotons	• Blast • Thermal • Transient Radiation • Electro Magnetic Pulse (EMP)



OPEN SEASON
(WAR)



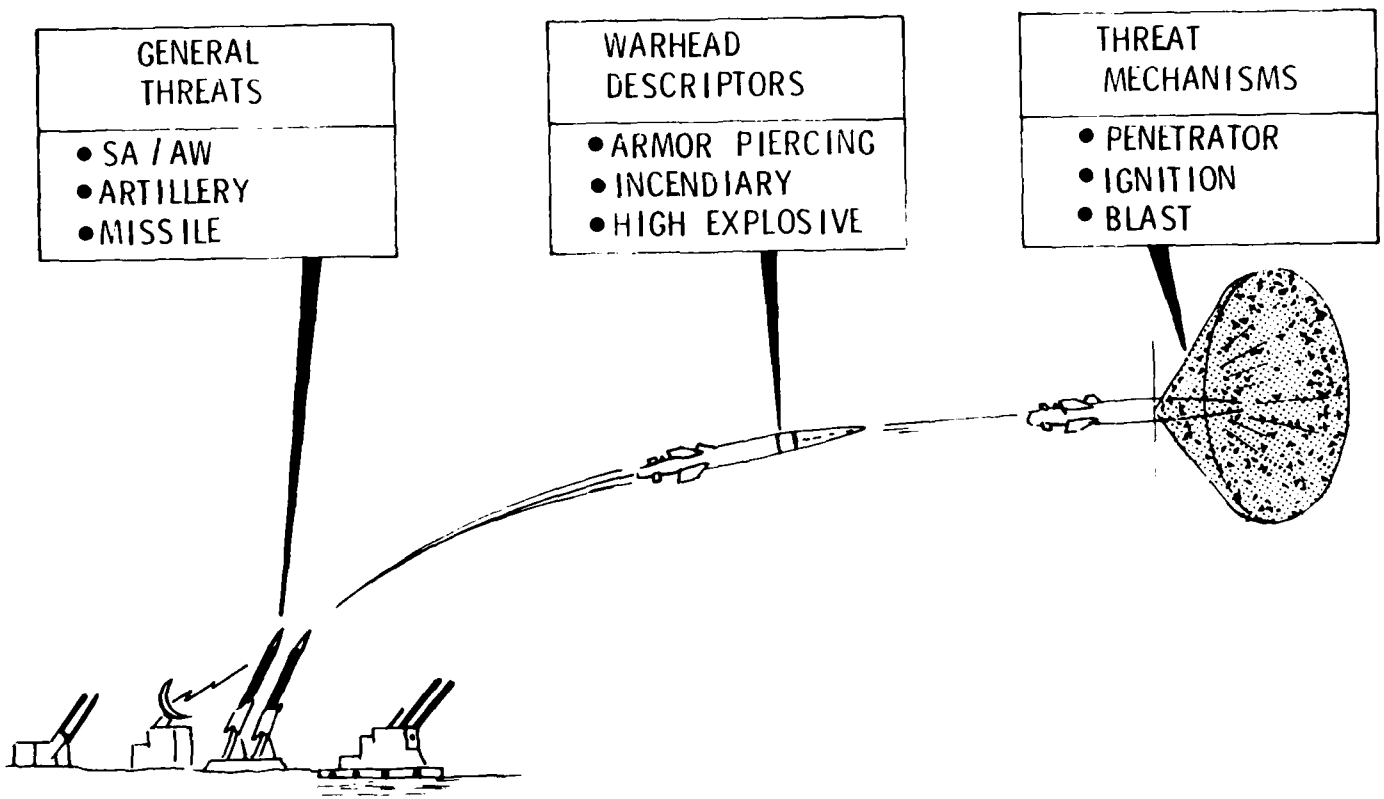
"No, it was not I who brought down your great screaming bird—someone else must have thrown the rock!"

AIR FORCE FLIGHT DYNAMICS LABORATORY

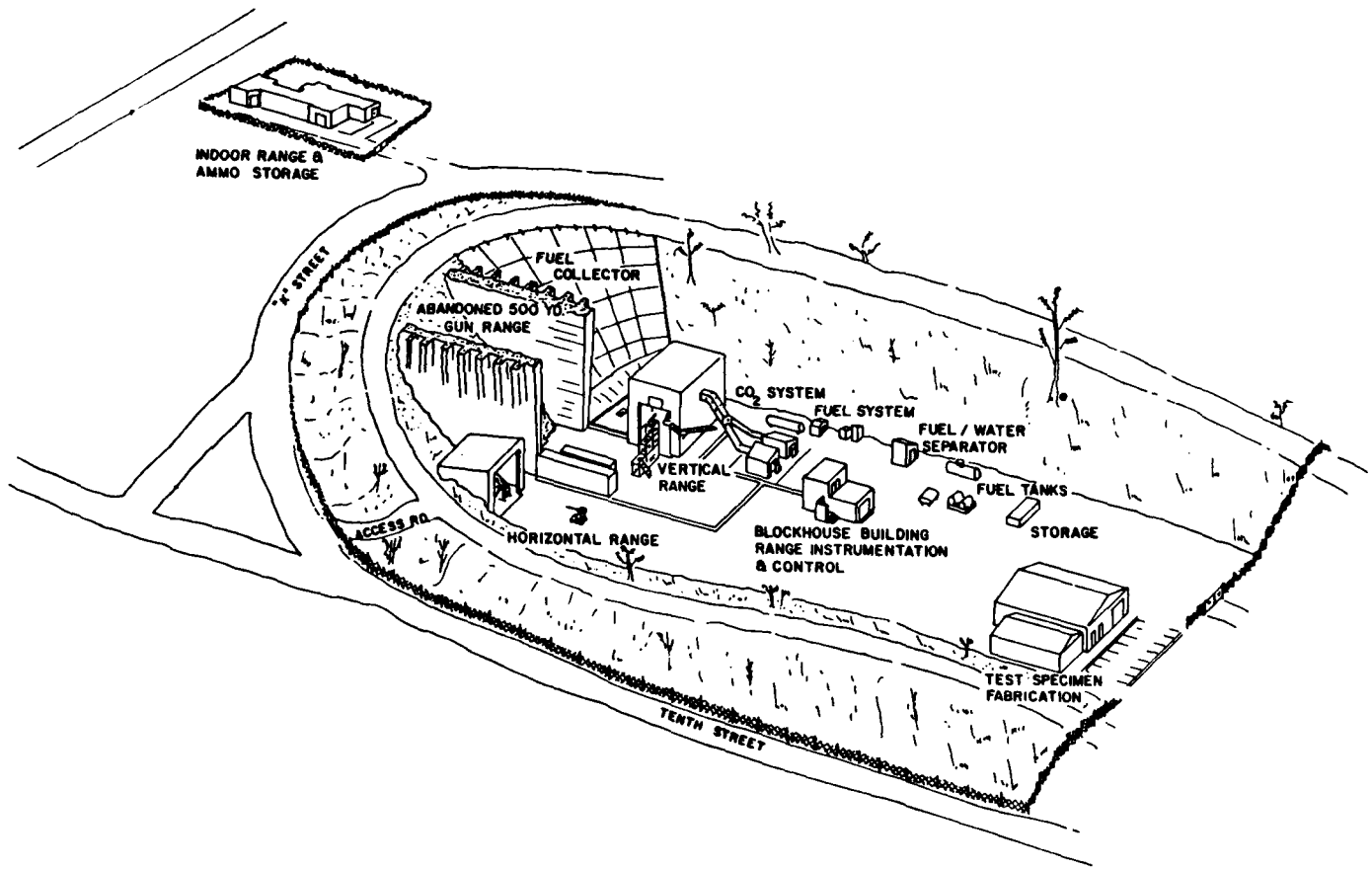
(NONNUCLEAR S/V)

- NONNUCLEAR SURVIVABILITY TECHNOLOGY DEVELOPMENT
- NONNUCLEAR WEAPONS EFFECTS DEFINITION
- TEST METHODS & TEST INSTRUMENTATION
- THREAT SIMULATION & TESTING
- EXPERIMENTAL DATA BASE
- COMBAT DATA (CDIC)

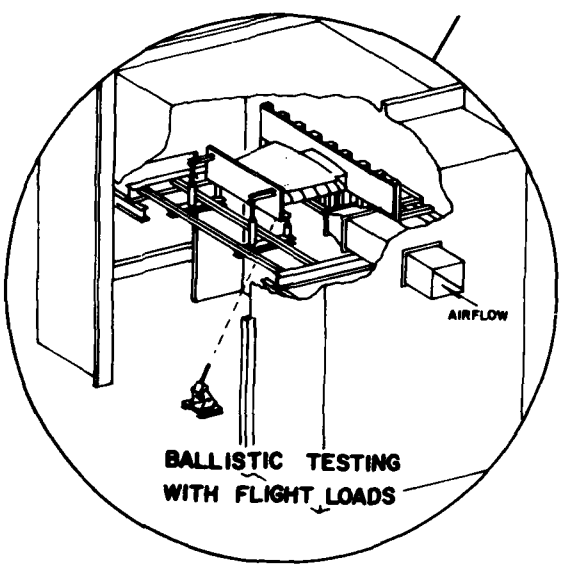
NON-NUCLEAR THREATS

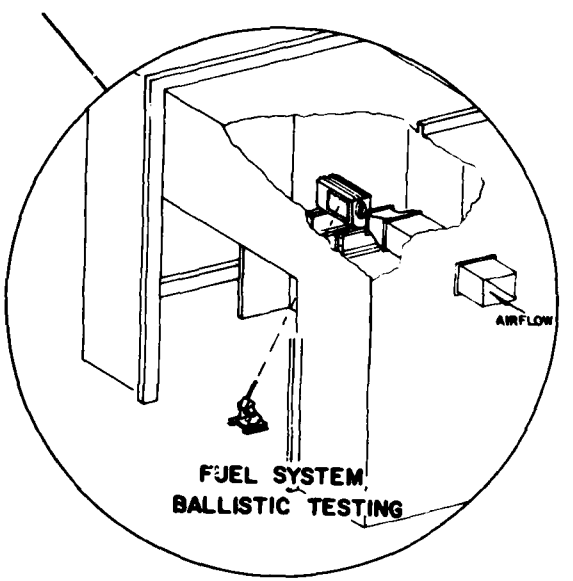


AIRCRAFT SURVIVABILITY RESEARCH FACILITY

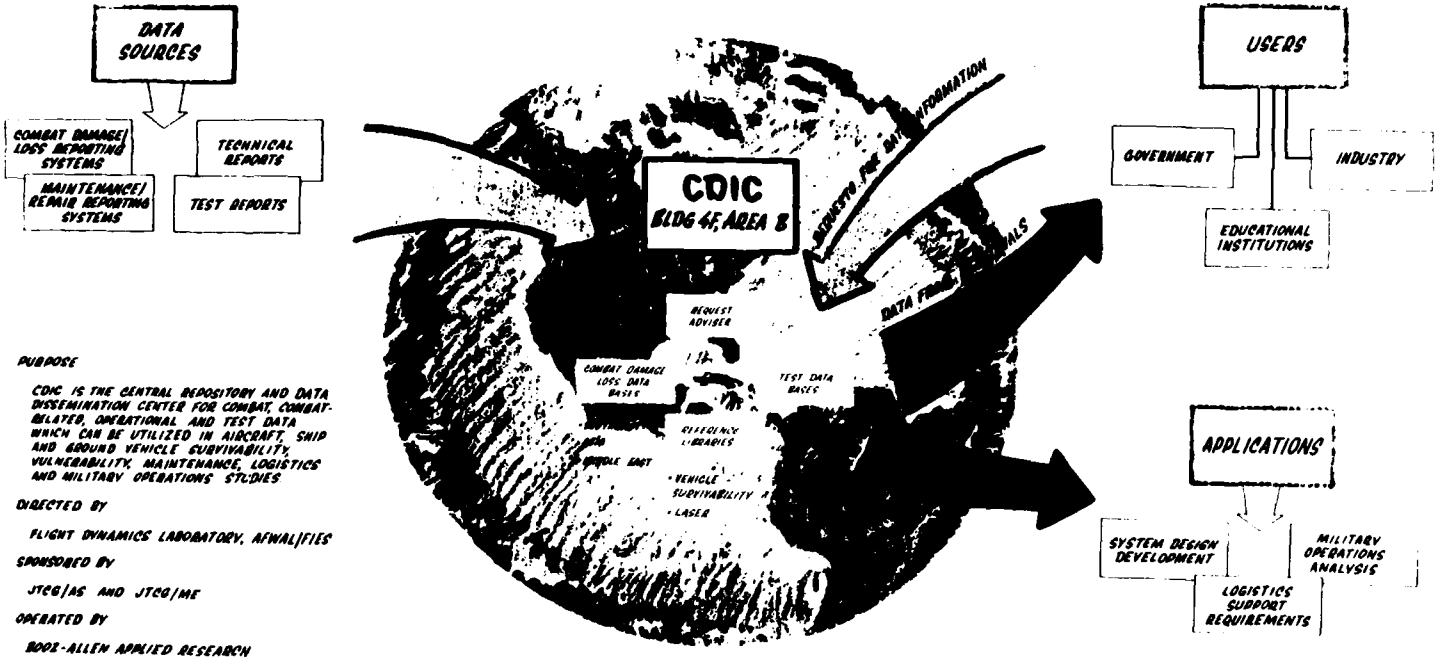


VERTICAL RANGE CAPABILITIES





COMBAT DATA INFORMATION CENTER (CDIC)



PURPOSE

CDIC IS THE CENTRAL REPOSITORY AND DATA DISSEMINATION CENTER FOR COMBAT, COMBAT-RELATED, OPERATIONAL AND TEST DATA WHICH CAN BE UTILIZED IN AIRCRAFT, SHIP AND GROUND VEHICLE SURVIVABILITY, VULNERABILITY, MAINTENANCE, LOGISTICS AND MILITARY OPERATIONS STUDIES

DIRECTED BY

FLIGHT DYNAMICS LABORATORY, AFWAL/FIES

SPONSORED BY

JTCG/AS AND JTCG/ME

OPERATED BY

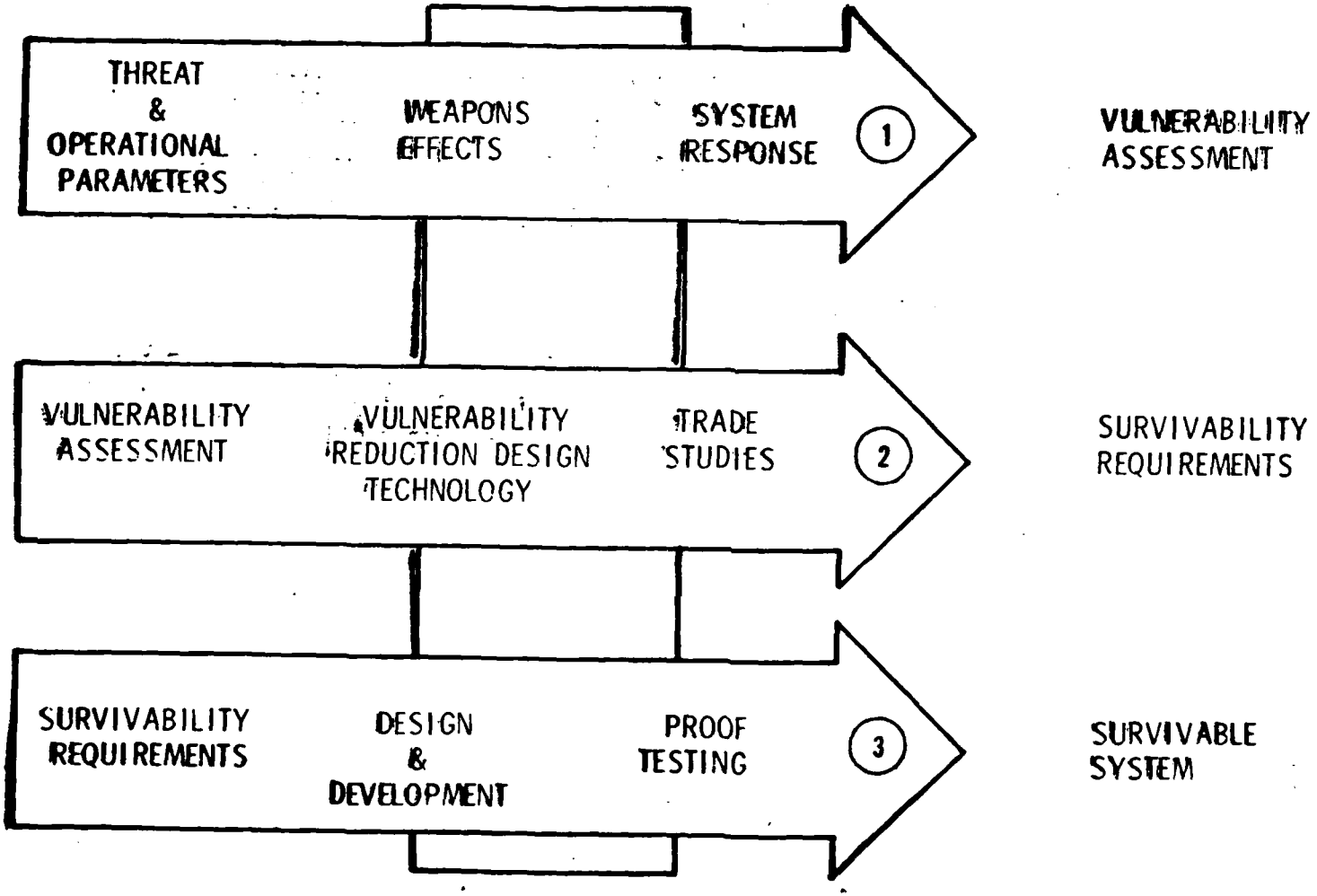
BOOZ-ALLEN APPLIED RESEARCH

AFWAL/FIES/CDIC WRIGHT-PATTERSON AIR FORCE BASE, OH 45433 PH (513) 255-4840/3056, AV 785-4840/3056

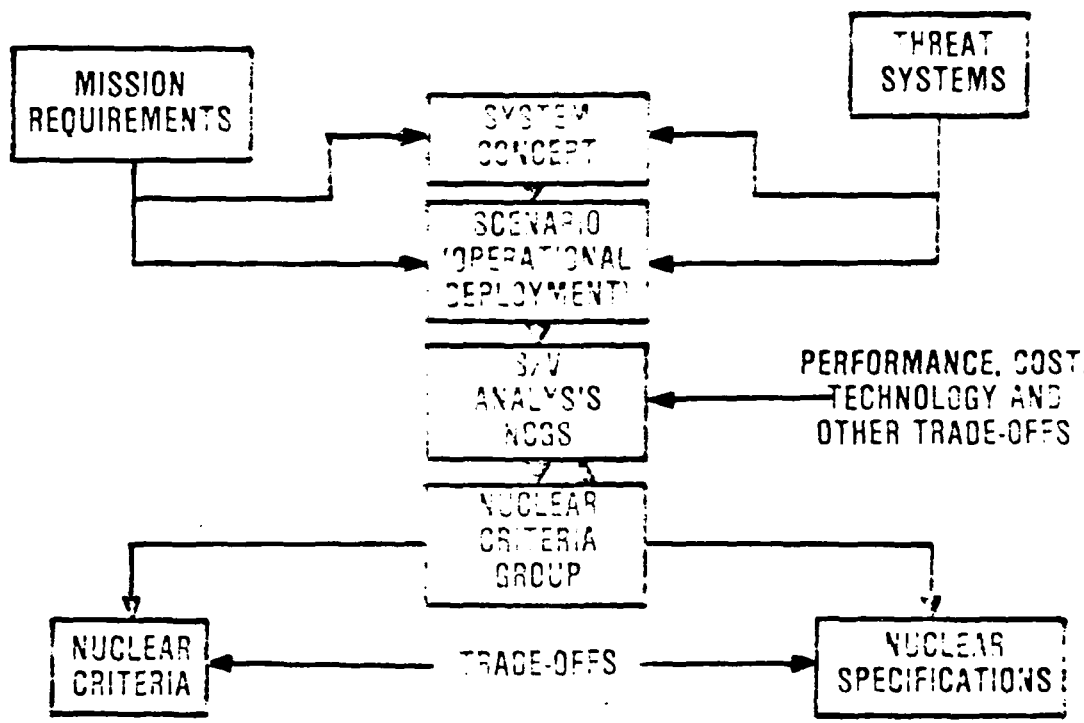
(14)

(16)

ELEMENTS OF ANY S/V PROGRAM



TAILORING NUCLEAR SPECIFICATIONS



SYSTEM S/V SPECIFICATIONS

CONFIGURATION

- PERFORMANCE
- DETECTABLES
- SURVIVABILITY LEVELS

SUBSYSTEMS

- SPECIFIC ALLOCATIONS
- SUBCONTRACT SPECIFICATIONS
- ASSOCIATE CONTRACTORS AGREEMENTS

AIR SURVIVAL

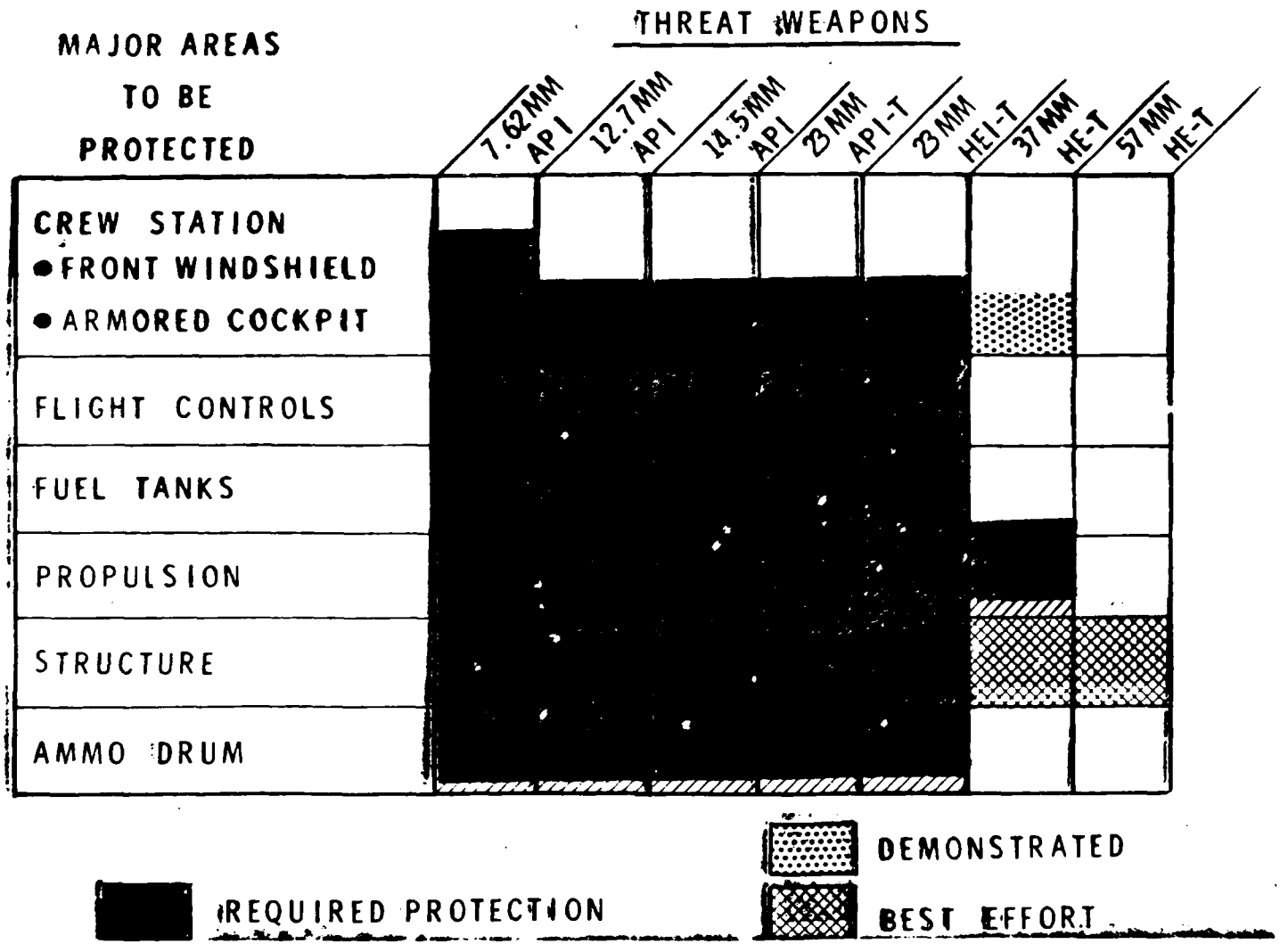
- FACTORS
  - PREVENT OR DELAY DETECTION
  - AVOID BEING HIT IF DETECTED
  - SURVIVE IF HIT

- DETECTION PROBABILITY
  - SIGNATURES
    - AURAL
    - INFRA-RED
    - OPTICAL
    - RADAR
  - ECM
  - TACTICS
  - TERRAIN

- HIT PROBABILITY
  - SPEED
  - MANEUVERABILITY
  - SIZE
  - ECM
  - TACTICS

- KILL PROBABILITY
  - SHIELDING
  - REDUNDANCY
  - SEPARATION
  - CONCENTRATION

A-10 ANTI-AIRCRAFT DESIGN REQUIREMENTS



ANALYSIS

VULNERABILITY

TARGET DESCRIPTION

VULNERABLE AREA CALCULATION

SYSTEM/SUBSYSTEM COMPONENT DETAILS

SURVIVABILITY

THREAT SCENARIO

THREAT SYSTEM CHARACTERISTICS

AIRCRAFT VULNERABILITY

PENETRATION AIDS

TACTICS

VULNERABILITY ASSESSMENT

- MANUAL CALCULATIONS
  - DRAWINGS
  - PLANIMETER
  - PENETRATION EQUATIONS/EMPIRICAL DATA
- COMPUTER CODES
  - TARGET DESCRIPTIONS
  - VULNERABLE AREA PROGRAMS
    - FASTGEN
    - COVART

PART II

FUTURE SYSTEMS

USAF SPECIFICATIONS / STANDARDS

(ASD INITIATIVE)

OBJECTIVE: TO DEVELOP PRIMARY SPECS & STDS TAILORABLE TO SYSTEMS WITH REQUIREMENTS STATED IN TERMS OF OPERATIONAL NEEDS AND HANDBOOKS TO PROVIDE TECHNICAL BACK-UP, RATIONALE, AND LESSONS LEARNED.

MILITARY STANDARD

AERONAUTICAL SYSTEMS MISSION COMPLETION IN A COMBAT ENVIRONMENT

AREAS OF CONCERN:

1. AVOIDING DETECTION
2. IF DETECTED, AVOID HIT
3. AVOIDING LOSS OF MISSION
4. AVOIDING LOSS OF CREW & AIRCRAFT AND / OR REDUCING % OF DETECTION, HIT OR LOSS

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OPERATIONAL NEEDS ADDRESSED:

- PRIMARY MISSION
  - FIRST DAY
  - SUBSEQUENT DAYS
- SECONDARY MISSION
  - FIRST DAY
  - SUBSEQUENT DAYS
- THREATS
  - NONNUCLEAR
  - NUCLEAR
- POST-COMBAT AVAILABILITY

EXCERPTS:

3.2.1.1 FIRST DAY. ON THE FIRST DAY OF COMBAT THE PRIMARY MISSION OBJECTIVE WILL BE _____. THE SYSTEM MUST PERFORM THIS MISSION ON _____% OF THE SORTIES FLOWN, AND MUST HAVE _____% OF ALL SORTIES RETURN TO A RECOVERY BASE.

3.4.1 FIRST SORTIE. SYSTEMS RETURNING TO A RECOVERY BASE AFTER THEIR FIRST SORTIE SHALL BE CAPABLE OF FIELD MAINTENANCE SUCH THAT _____% OF THE SYSTEMS ARE CAPABLE OF PERFORMING THE SUBSEQUENT MISSION OF _____ WITHIN _____ HOURS.

470

EXCERPTS — CONT'D:

3.5.1 IR SIGNATURE. THE SYSTEM SHALL BE DESIGNED TO AVOID DETECTION BY THE FOLLOWING IR SENSORS _____ AT RANGES OF _____ ON _____% OF ITS ENCOUNTERS AT THE FOLLOWING ASPECT ANGLES _____ AND IN THE FOLLOWING ATMOSPHERIC CONDITIONS _____.

3.8.8 ARMOR PIERCING PROJECTILES. THE SYSTEM SHALL BE DESIGNED TO COMPLETE THE _____ MISSION(S) AFTER IMPACT FROM A RANGE OF ____ BY A ____ THREAT IN THE FOLLOWING FLIGHT CONDITIONS _____, AND TO COMPLETE THE _____ MISSION(S) AFTER IMPACT FROM ____ PROJECTILES HAVING A DISTRIBUTION OF _____ FIRED FROM A RANGE OF _____ BY A _____ THREAT IN THE FOLLOWING FLIGHT CONDITION _____. THE SYSTEM SHALL BE ABLE TO FLY _____ AFTER IMPACT FROM THE SINGLE PROJECTILE, AND _____ AFTER IMPACT FROM MULTIPLE PROJECTILES.

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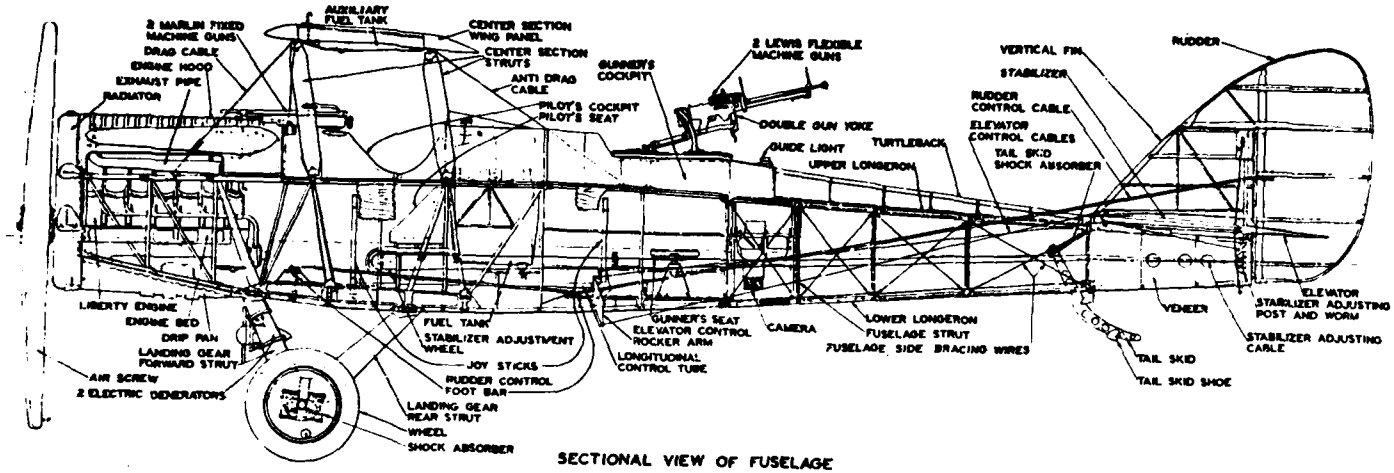
EXCERPTS — CONT'D:

4.5.2.2 TEST (RCS). THE FINAL SYSTEM PRODUCTION DESIGN SHALL BE VALIDATED THROUGH TESTS IN THE _____ FACILITY.

CURRENT STATUS

- MILITARY STANDARD -- DRAFT COMPLETED, CURRENTLY IN TECHNICAL COMMITTEE REVIEW.
- HANDBOOK -- IN PREPARATION, APPROXIMATELY 25% COMPLETED. AIMING FOR JUNE 1981 DRAFT.



SECTIONAL VIEW OF FUSELAGE

DEHAVILLAND 4 WITH LIBERTY "12"

T.D.B./P.P.-7/16

474

T.D.B./P.P.-7/16

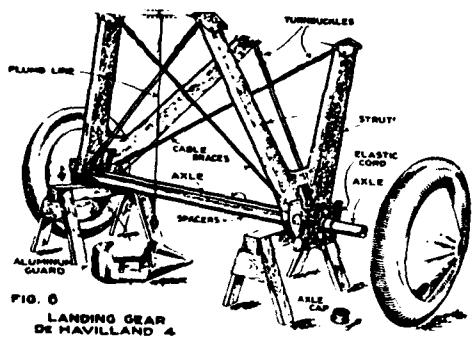
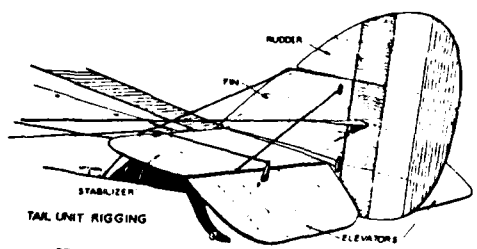


FIG. 6
LANDING GEAR
DE HAVILLAND 4

DeHavilland-4 (LIBERTY 12)

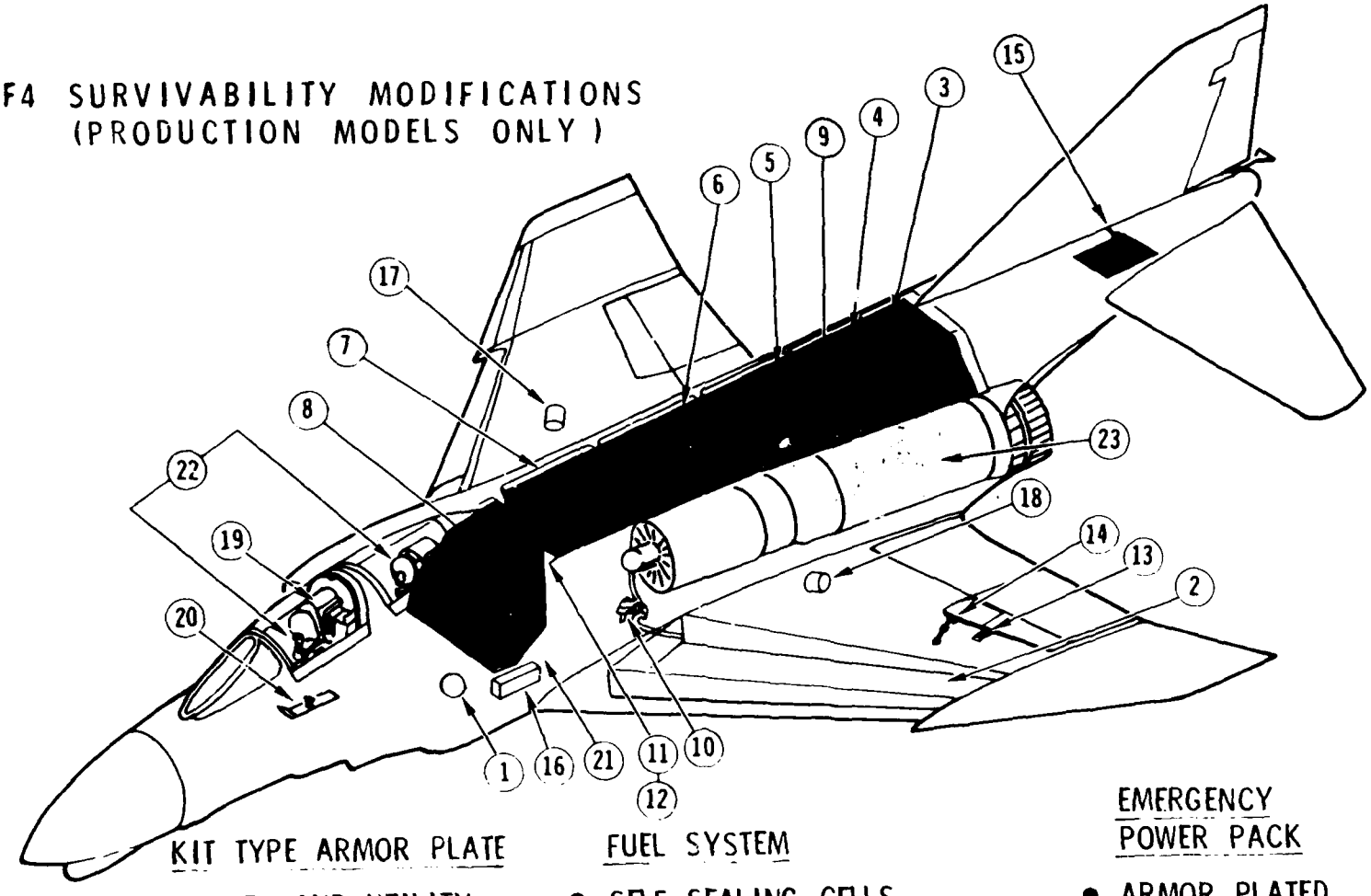
T.D.B./P.P.-7/16



TAIL UNIT RIGGING
DE HAVILLAND 4

FIG 12

F4 SURVIVABILITY MODIFICATIONS (PRODUCTION MODELS ONLY)



KIT TYPE ARMOR PLATE

- OXYGEN AND UTILITY HYDRAULIC BAY DOORS (EXTERNAL ARMOR)

FUEL SYSTEM

- SELF SEALING CELLS
- RETICULATED FOAM
- SELF SEALING LINES AND COMPONENTS
- SEPARATED FUEL FEED SYSTEM

EMERGENCY POWER PACK

- ARMOR PLATED EMERGENCY HYDRAULIC STABILATOR POWER SYSTEM (33)

AD-A113 556 JOINT TECHNICAL COORDINATING GROUP ON AIRCRAFT SURVIV--ETC F/G 1/3
PROCEEDINGS, A WORKSHOP IN SURVIVABILITY AND COMPUTER-AIDED DES--ETC(U)
1981

UNCLASSIFIED JTCG/AS-81-O-001 NL

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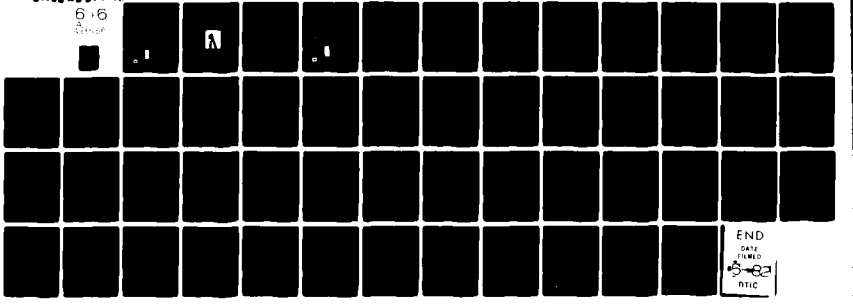

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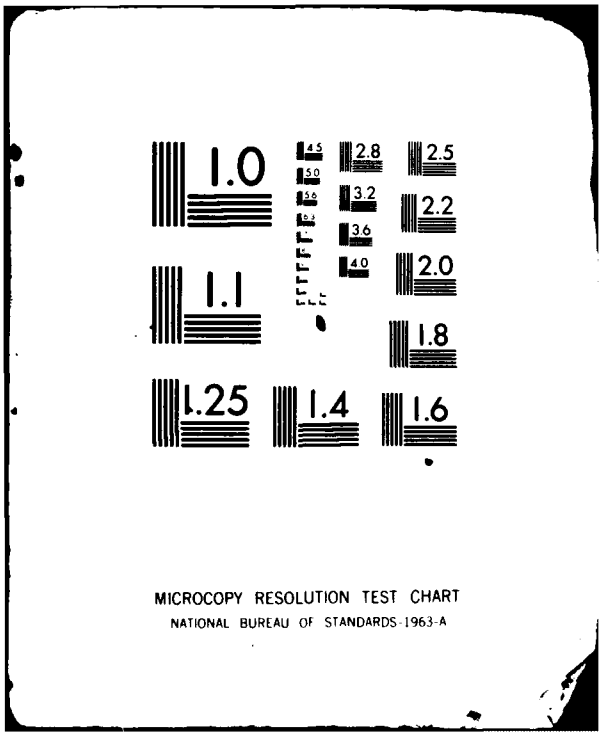
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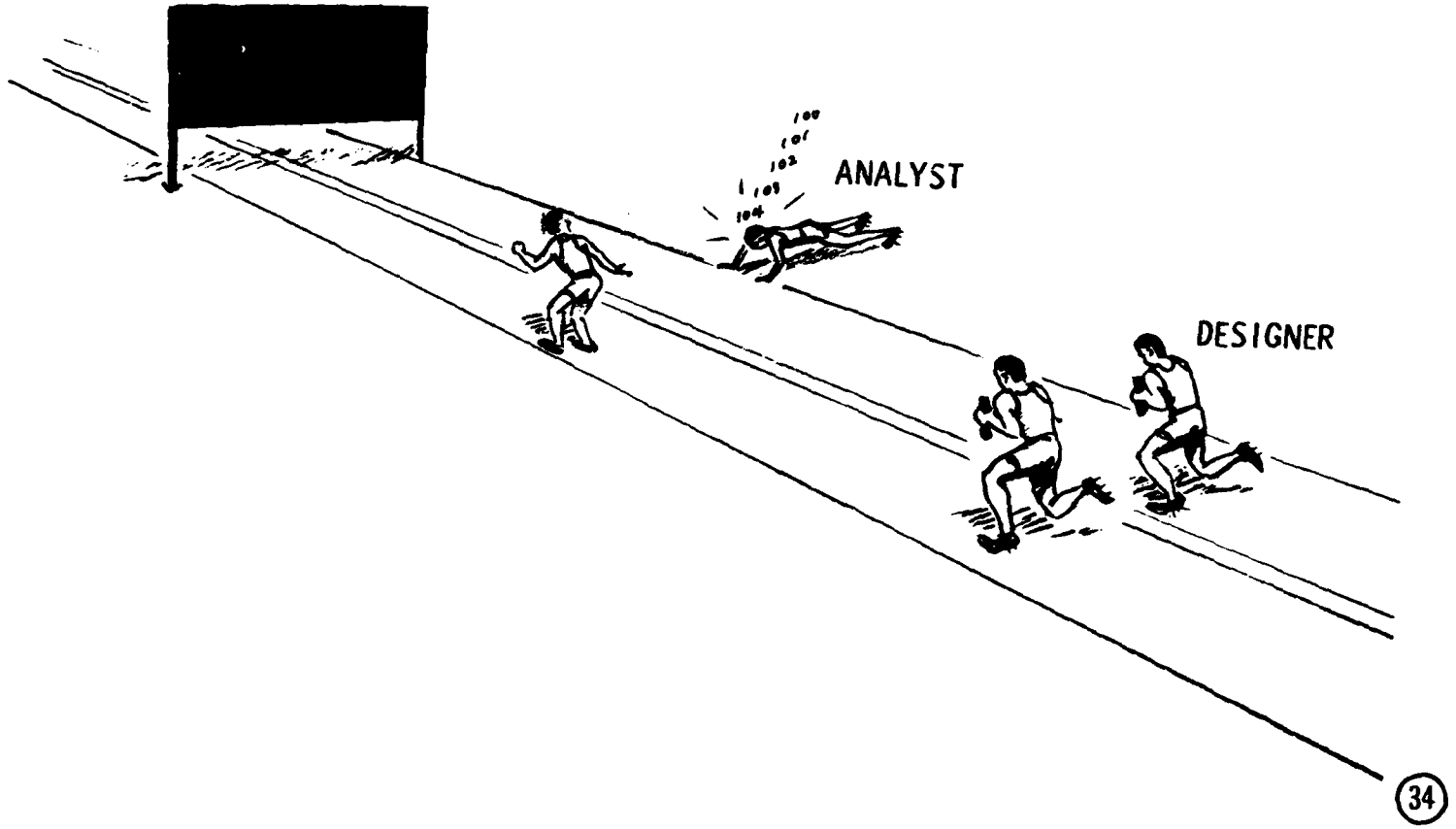
5.6
MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

TEAM EFFORT

FDTS 7-9-18



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34

SURVIVABILITY/VULNERABILITY CONSIDERATIONS IN CONCEPTUAL DESIGN

Joseph A. Arrighi
Deputy Director of Engineering
Fairchild Republic Company
Farmingdale, New York

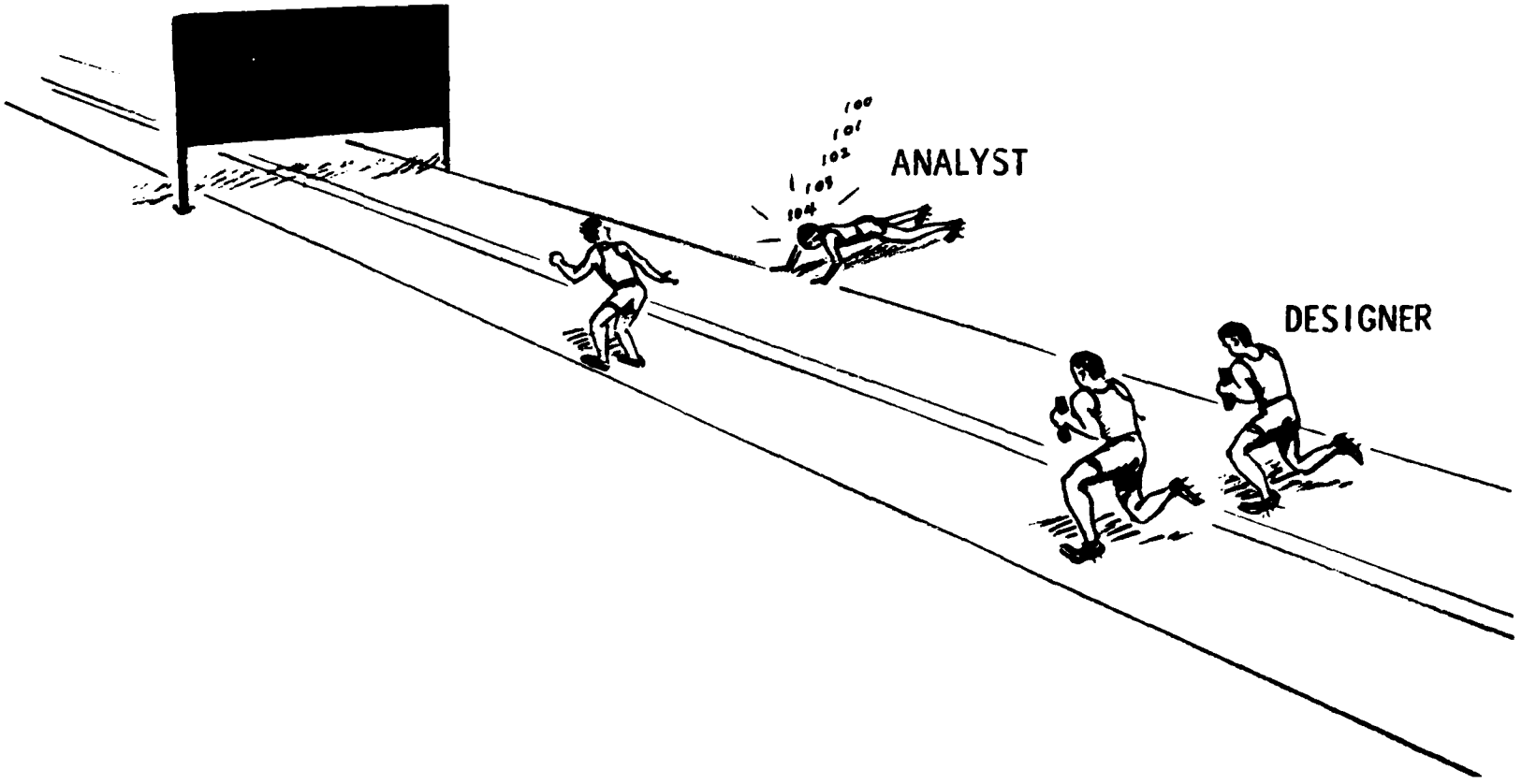
SURVIVABILITY/VULNERABILITY CONSIDERATIONS IN CONCEPTUAL DESIGN

Joseph A. Arrighi
Deputy Director of Engineering
Fairchild Republic Company
Farmingdale, New York

Fairchild Republic has recently completed a USAF/FDL contract, "Survivability Methodology for Aircraft Conceptual Design" (Contract No. F33615-78-C-3426), sponsored by the JTCG/AS. While the scope of the total contract is outlined and some of the methodology and results are illustrated, attention is focused on Task I, and its four subtasks, which is specifically appropriate to this symposium/workshop. The conceptual design process is discussed, and the role which can be played by the S/V analyst is defined. A framework for introducing graphics in general, and CAD in particular, into survivability considerations is thus developed.

TEAM EFFORT

FDTS 7-9-18



S/V IS PART OF CONCEPTUAL DESIGN

AS A RESULT OF A RECENT STUDY CONTRACT PERFORMED BY FRC, AND THE METHODOLOGY DEVELOPED AS A CONSEQUENCE, WE BELIEVE THAT S/V CAN BE MADE AN INTEGRAL PART OF CONCEPTUAL DESIGN OF AIRCRAFT. THE CONTRACT PERFORMED WAS WITH THE S/V BRANCH OF THE FLIGHT DYNAMICS LABORATORY AND WAS SPONSORED BY THE JTCG/AS.

I WILL DESCRIBE THE TASKS INVOLVED, TELL YOU OF THE CONTENT OF TASK I, AND, BECAUSE IT IS SO PERTINENT TO THIS WORKSHOP, SPEND MOST OF MY TIME IN THAT TASK. BUT, I'LL ALSO BRIEFLY ILLUSTRATE THE METHODOLOGY WHICH WAS DEVELOPED AND SHOW YOU SOME OF THE VALIDATION OF THE METHODOLOGY. I'LL ALSO DRAW CONCLUSIONS.

WHAT WAS INVOLVED IN THE STUDY?

S/V IS PART OF CONCEPTUAL DESIGN

- FDL/FRC CONTRACT (JTCG/AS)
- 3 TASKS
- TASK I
- METHODOLOGY ILLUSTRATED
- DEMONSTRATED – A-10A, OV-10A
- RESULTS

COMPLETED 3 TASKS

THERE WERE THREE TASKS INVOLVED. THE FIRST REQUIRED AN INVESTIGATION OF CURRENT PRACTICES BE MADE. THE SECOND DEFINED A METHODOLOGY TO BE DEVELOPED, AND, THE THIRD REQUIRED ANALYSES OF SAMPLE CASES, USING THE METHODOLOGY, FOR VALIDATION AND/OR REVISION PURPOSES.

TASK I WAS THE SET UP TASK. IT'S UNDERLYING PURPOSE WAS TO -----

COMPLETED 3 TASKS

I. INVESTIGATE

II. DEVELOP METHODOLGY

III. PERFORM SAMPLE CASES

FIT S/V ANALYST INTO CONCEPTUAL DESIGN PROCESS

----- DETERMINE HOW THE S/V ANALYST COULD BE FIT INTO THE CONCEPTUAL DESIGN PROCESS SO THAT S/V WOULD BECOME AN INTEGRAL PART.

TASK I CALLED FOR INVESTIGATING AND IDENTIFYING THE SO-CALLED "CONTRIBUTORS" TO A/C SURVIVABILITY,TO SET FORTH WHAT ARE THE CURRENT APPROACHES TO ASSESSING, ENHANCING AND TRADING-OFF SURVIVABILITY, WHAT ARE THE CURRENT CONCEPTUAL DESIGN PRACTICES IN THE FIRST PLACE, AND WHAT ARE THE PROBLEMS AND DEFICIENCIES INVOLVED IN ALL OF THIS. THESE ARE FOUR SUB-TASKS TO TASK I AND I'LL DWELL ON EACH IN TURN.

FROM THE OUTSET, IT WAS NECESSARY TO DEFINE WHAT IS MEANT BY SURVIVABILITY CONTRIBUTORS.

FIT S/V ANALYST INTO CONCEPTUAL DESIGN PROCESS

- INVESTIGATE/IDENTIFY CONTRIBUTORS
- CURRENT APPROACHES
  ASSESS/ENHANCE/TRADE-OFF
- CONCEPTUAL DESIGN PRACTICES
- PROBLEMS AND DEFICIENCIES

SURVIVABILITY CONTRIBUTORS DEFINED

IN THE STUDY, SURVIVABILITY CONTRIBUTORS HAVE BEEN DEFINED AS THOSE DESIGN CHARACTERISTICS WHICH ARE NORMALLY INCORPORATED IN THE DESIGN OF AN AIRPLANE AND WHICH CAN BE REARRANGED, IMPROVED UPON OR OTHERWISE ADJUSTED TO ACHIEVE MAXIMUM BENEFIT TO SURVIVABILITY. IN OTHER WORDS. CONTRIBUTORS ARE ALREADY THERE AND ARE NOT ADDED JUST BECAUSE OF SURVIVABILITY.

IN GENERAL. THERE ARE TWO CATEGORIES OF CONTRIBUTORS. --------

SURVIVABILITY CONTRIBUTORS DEFINED

"- - - - DESIGN CHARACTERISTICS NORMALLY INCORPORATED - - - WHICH CAN BE RE-ARRANGED, IMPROVED UPON OR - - - ADJUSTED TO ACHIEVE MAXIMUM BENEFIT TO SURVIVABILITY."

THERE ARE 2 CATEGORIES OF CONTRIBUTORS

---------- THOSE WHICH ARE CONFIGURATION SENSITIVE AND THOSE WHICH ARE PERFORMANCE SENSITIVE. THE FIRST ARE GEOMETRY AND HARDWARE RELATED AND THE SECOND ARE AGILITY RELATED.

THESE ARE SPECIFICALLY INTER-RELATED IN CURRENT CONCEPTUAL DESIGN PRACTICES.

THERE ARE 2 CATEGORIES OF CONTRIBUTORS

CONFIGURATION SENSITIVE

CONTRIBUTIONS: VULNERABLE AREA
GEOMETRY, HARDWARE RELATED

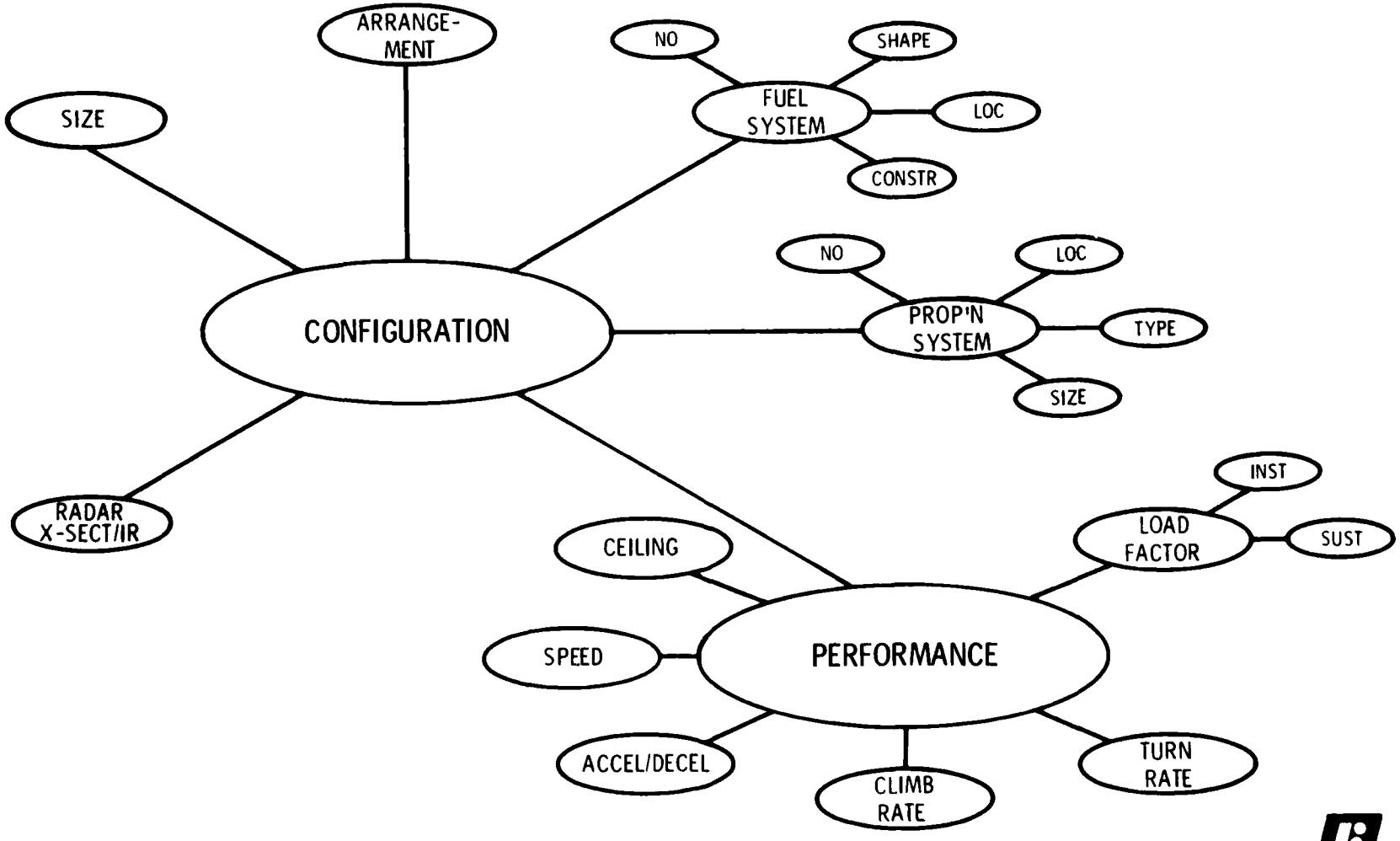
PERFORMANCE SENSITIVE

CONTRIBUTIONS: AGILITY IN END GAME

CONTRIBUTORS ARE INTER-RELATED

SHOWN GRAPHICALLY ARE SOME OF THE CONTRIBUTORS OF BOTH TYPES. AIRCRAFT SIZE, ARRANGEMENT, THE NUMBER, SHAPE AND LOCATION OF FUEL CELLS, THE TYPE AND SIZE OF ENGINES ARE ALL CONFIGURATION SENSITIVE SURVIVABILITY CONTRIBUTORS. SPEED AT VARIOUS ALTITUDES, CLIMB RATE AND THE ABILITY TO IMPOSE INSTANTANEOUS AND SUSTAINED LOAD FACTORS ARE PERFORMANCE SENSITIVE CONTRIBUTORS, MANY OF WHICH ARE DEPENDENT ON SPECIFIC EXCESS POWER AVAILABLE. THE INTER-LINK BETWEEN THEM, REPRESENTED BY THE DIAGONAL BAR (⧸) IS THE CONCEPTUAL DESIGN PROCESS ITSELF.

CONTRIBUTORS ARE INTER-RELATED



CONTRIBUTORS PLAY THESE ROLES

IF WE TRY TO UNDERSTAND THE ROLE PLAYED BY THE VARIOUS CONTRIBUTORS THEN THE RESULT WILL LOOK LIKE WHAT IS DISPLAYED IN THIS TABLE. IN GENERAL, THE CONFIGURATION SENSITIVE CONTRIBUTORS, EXCEPT FOR THE OBSERVABLES, HAVE THEIR GREATEST INFLUENCE ON THE VULNERABILITY OF THE AIRPLANE WHILE THE PERFORMANCE SENSITIVE CONTRIBUTORS HAVE A LARGE INFLUENCE ON SURVIVABILITY IN THE "END GAME" ANALYSES.

SO MUCH FOR THE SURVIVABILITY CONTRIBUTORS. HOW IS SURVIVABILITY ASSESSED?

CONTRIBUTORS PLAY THESE ROLES

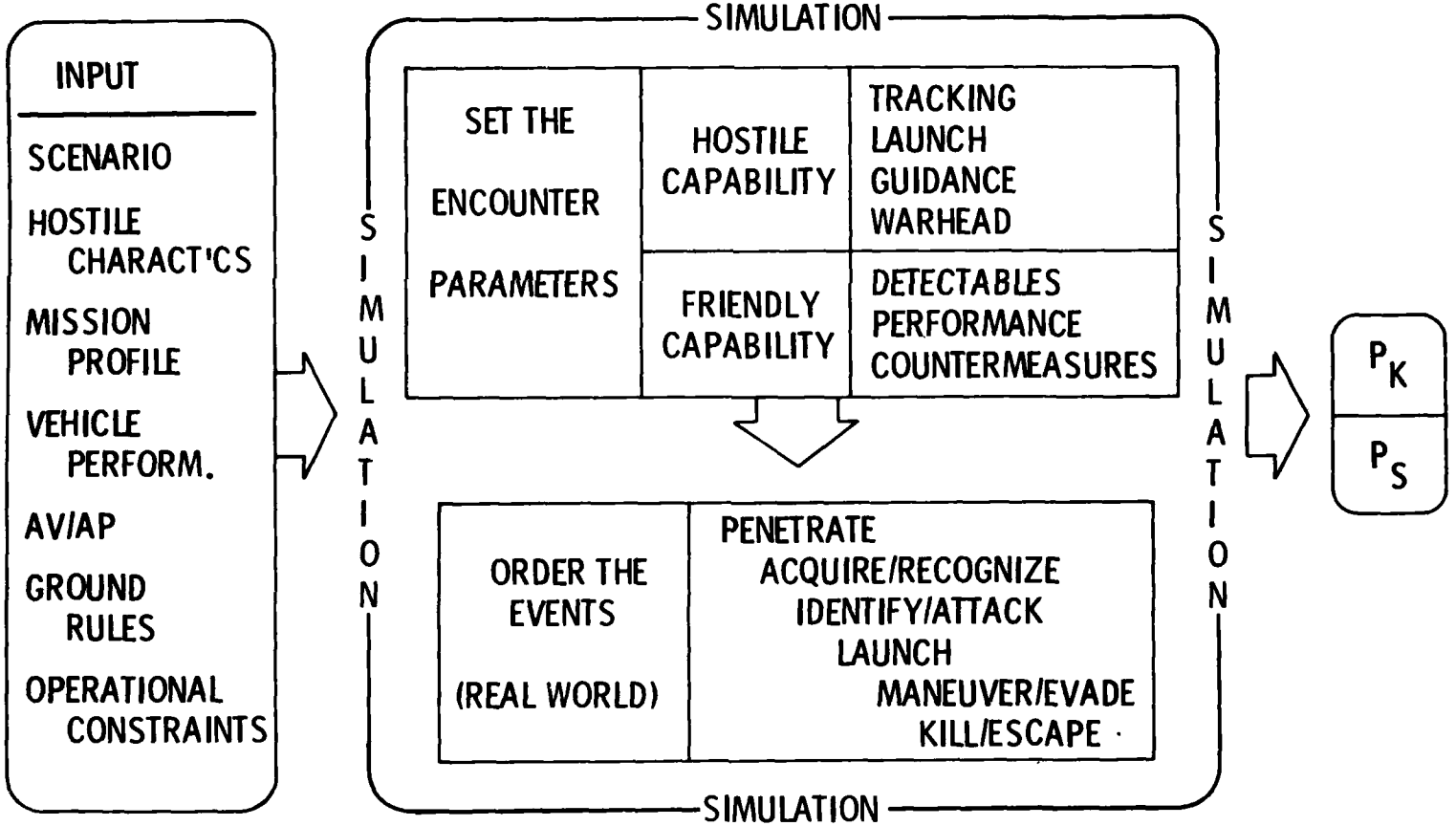
CONTRIBUTOR	ROLE	
	V	S
CONFIGURATION		
SIZE	✓	✓
ARRANGEMENT	✓	
FUEL SYSTEM	✓	
PROPULSION SYS.	✓	
ARMAMENT	✓	
OBSERVABLES		✓
PERFORMANCE		✓

ASSESSMENT APPROACH IS WELL ESTABLISHED

THE ASSESSMENT APPROACH IS WELL ESTABLISHED IN THE AIRCRAFT DESIGN COMMUNITY. BOTH HOSTILE AND FRIENDLY ENCOUNTER PARAMETERS ARE DETERMINED AND THE REAL WORLD EVENTS ARE ORDERED. THESE ARE SIMULATED IN END GAME MODELS WHICH ARE EXERCISED IN MULTIPLE COMPUTER RUNS. INPUT TO THESE COMPUTER MODELS, IN THE FORM OF GROUND AND AIR SCENARIOS, THE CHARACTERISTICS OF HOSTILE AND FRIENDLY WEAPONS, AND OTHER INFORMATION AND DATA, ARE MADE. AND, EITHER THE KILL OR THE SURVIVAL PROBABILITIES, AS FUNCTIONS OF INPUT VARIABLES, RESULT.

HOWEVER - - - - - -

ASSESSMENT APPROACH IS WELL ESTABLISHED



ASSESSMENT ACCURACY IS QUESTIONABLE

--------- THE ACCURACY OF RESULTS IS QUESTIONABLE. THE MODELS THEMSELVES CANNOT TRULY REPRESENT ALL REAL WORLD EVENTS AND THE HEAVY DEPENDENCE ON DEFAULT VALUES INSTEAD OF MORE DEFINITE INPUTS BOTH CONTRIBUTE TO INACCURACY. IT IS COMMON PRACTICE TO DISBELIEVE THE ABSOLUTE VALUE OF THE RESULTS AND TO CONSTRAIN THEIR INTERPRETATION TO COMPARISONS OF LIKE VEHICLES EXERCISED IN SIMILAR SITUATIONS.

AND NOW, WHAT IS THE CURRENT APPROACH TO SURVIVABILITY ENHANCEMENT - BEFORE THAT THOUGH, ---------

ASSESSMENT ACCURACY IS QUESTIONABLE

- DEFAULT

  VS

  DEFINITIVE

- COMPARATIVE

ENHANCEMENT IS DEFINED

--------- WE MUST DEFINE WHAT IS MEANT BY "ENHANCEMENT". AS DISTINCT FROM SURVIVABILITY CONTRIBUTORS, SURVIVABILITY ENHANCEMENT IS DEFINED AS ANY ADDITION OR MODIFICATION TO A BASELINE AIRCRAFT, NOT NORMALLY CONSIDERED IN CONCEPTUAL DESIGN, FOR THE SOLE PURPOSE OF IMPROVING ITS SURVIVABILITY CHARACTERISTICS. IN GENERAL, ENHANCEMENTS "HARDEN" THE AIRCRAFT AGAINST ATTACK.

THE BASIC DESIGN APPROACH, -------

ENHANCEMENT IS DEFINED

- ADDITION/MODIFICATION
- NOT NORMALLY CONSIDERED
- IMPROVE SURVIVABILITY CHARACTERISTICS

"HARDEN"

ENHANCEMENT APPROACH NOT WELL INTEGRATED

------- WHICH IS NOT WELL INTEGRATED WITH THE CONCEPTUAL DESIGN PROCESS, IS TO COUNTER A THREAT'S FUNCTIONAL ELEMENTS. THESE ELEMENTS ARE THE THREAT'S ABILITY TO DETECT, LOCATE, TRACK, AIM AND CONTROL, AND IT'S TERMINAL EFFECTS.

THESE CAN BE COUNTERED BY EITHER PASSIVE OR ACTIVE MEANS. LISTED IN THE VU-GRAPH ARE THE USUAL MEANS EMPLOYED.

THE LAST OF THE TRIO OF CURRENT APPROACHES STUDIED IS SURVIVABILITY TRADE-OFFS.

ENHANCEMENT APPROACH NOT WELL INTEGRATED

- BASIC APPROACH:
  - COUNTER FUNCTIONAL ELEMENTS
- PASSIVE OR ACTIVE?
- COMMON PRACTICE:
  - DETECTION/LOCATION ___ ___ ___ ___ ACTIVE
  - TRACK/AIM/FIRE CONTROL ___ ___ ___ ACTIVE
  - TERMINAL EFFECTS ___ ___ ___ ___ PASSIVE

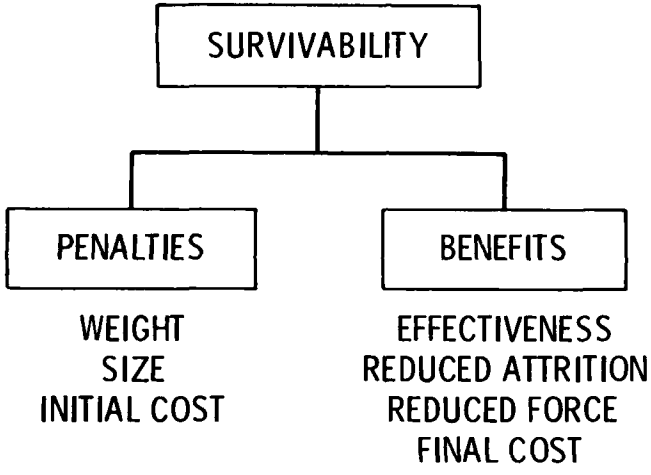
TRADE-OFFS NOT ALL INCLUSIVE

SUCH TRADES IN CONCEPTUAL DESIGN ARE NOT ALL INCLUSIVE. THE GENERAL APPROACH IS TO STUDY VARIOUS QUALITIES, RELIABILITY, MAINTAINABILITY, ETC., OF WHICH SURVIVABILITY IS ONE, TO BALANCE PENALTIES AGAINST BENEFITS, AND TO CHOOSE THE MORE DESIRABLE CHARACTERISTICS BASED ON THE DEFINED DATA. WEIGHT, SIZE AND INITIAL COST PENALTIES CAN PRODUCE BENEFITS LIKE INCREASED EFFECTIVENESS, REDUCED ATTRITION, SMALLER FORCE AND REDUCED LIFE CYCLE COSTS.

COMMON PRACTICE DOES INCLUDE THE PERFORMANCE SENSITIVE SURVIVABILITY CONTRIBUTORS AS PART OF THE CONCEPTUAL DESIGN PROCESS BUT FAILS TO MAKE ADEQUATE PROVISION FOR SURVIVABILITY ENHANCEMENT FEATURES AND FOR VULNERABILITY ASSESSMENT REQUIREMENTS AND THE IMPORTANT INTER-RELATIONSHIP BETWEEN THEM. THIS IS TRUE BECAUSE OF FUNDAMENTAL LIMITATIONS ON REQUIRED DATA.

TRADE-OFFS NOT ALL INCLUSIVE

IN GENERAL



SPECIFICALLY

SURVIVABILITY CONTRIBUTORS	√	[PERFORMANCE SENSITIVE]
SURVIVABILITY ENHANCEMENT	✗	
VULNERABILITY ASSESSMENT	✗	

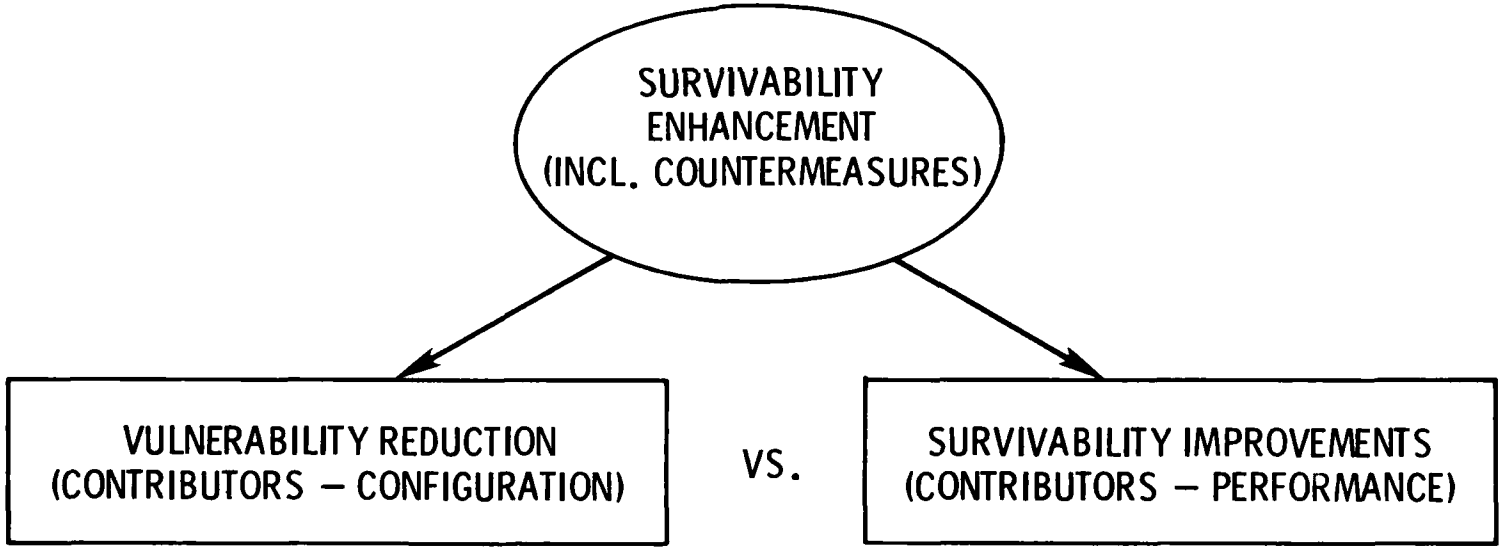
DATA LIMITED

BALANCED TRADE-OFF APPROACH REQUIRED

A **BALANCED TRADE-OFF** CAPABILITY IS REQUIRED IN WHICH VULNERABILITY REDUCTIONS CAN BE BALANCED AGAINST SURVIVABILITY IMPROVEMENTS WITH AND WITHOUT SURVIVABILITY ENHANCEMENT FEATURES. THE CONCEPTUAL DESIGN PROCESS IS FUNDAMENTALLY WELL ARRANGED TO SUPPLY THIS CAPABILITY. IT LACKS ONLY THE METHODOLOGY FOR EMBRACING SURVIVABILITY ENHANCEMENT AND VULNERABILITY REDUCTION.

BUT, BEFORE WE GET INTO THIS, LET'S DEFINE TERMS LIKE CONCEPTUAL, CONCEPTUAL DESIGN, AND CONCEPT FORMULATION.

BALANCED TRADE-OFF APPROACH REQUIRED

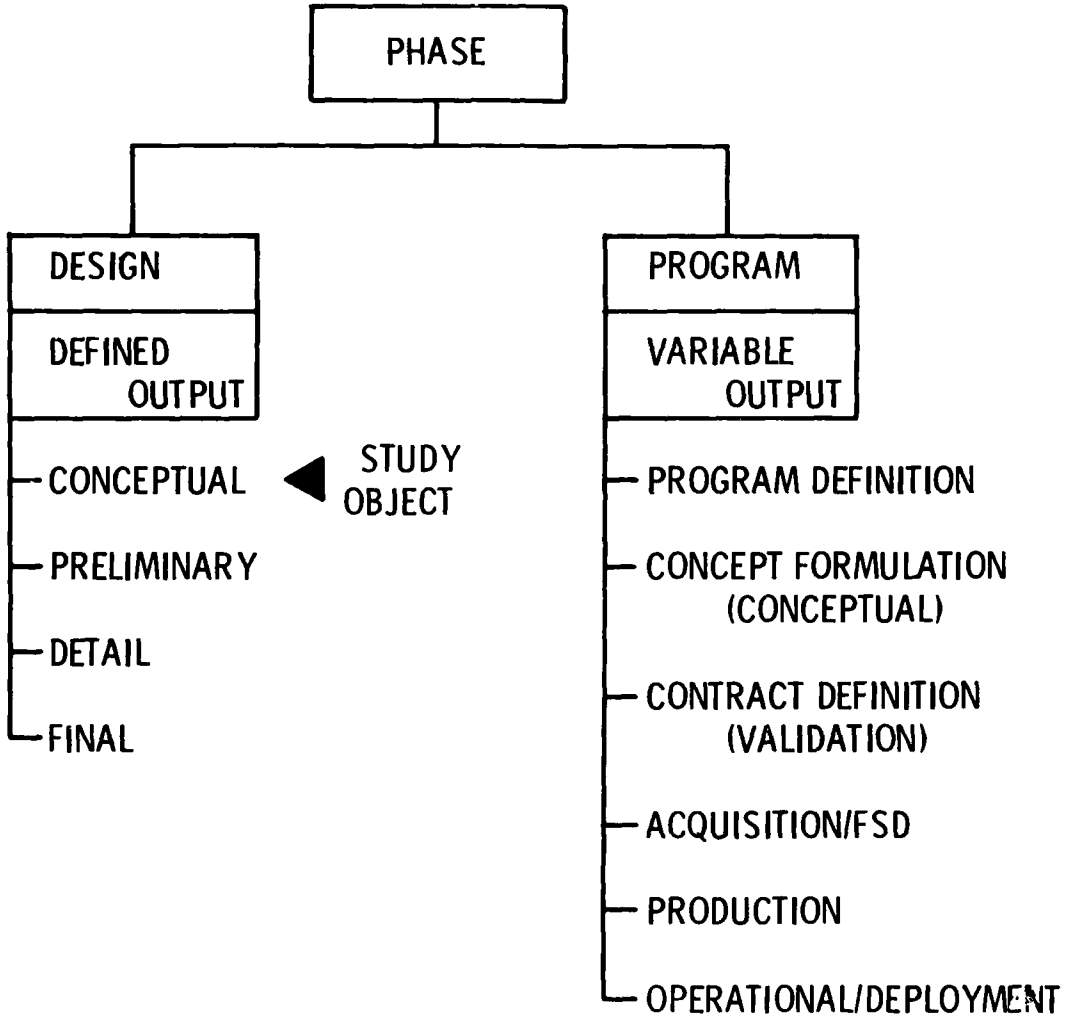


"CONCEPTUAL" IS RELATED TO A DESIGN PHASE

SHOWN ON THIS VU-GRAPH ARE TWO DISTINCTLY DIFFERENT PHASING SCHEMES, ONE IS DESIGN ORIENTED IN WHICH THE OUTPUT IS WELL DEFINED, AND THE OTHER IS PROGRAM ORIENTED IN WHICH THE OUTPUT CAN BE VARIABLE. THE CONTRACTED STUDY WAS PERFORMED IN THE DESIGN ORIENTATION IN WHICH "CONCEPTUAL DESIGN" IS THE FIRST OF A SEQUENCE OF INCREASING DESIGN DEFINITIONS AND LEVELS OF DETAIL.

"CONCEPTUAL DESIGN" IS DEFINED AS ----------

"CONCEPTUAL" IS RELATED TO A DESIGN PHASE



"CONCEPTUAL DESIGN" IS DEFINED

------- A SYSTEMIZED WORK PROCESS WHICH CONVERTS A SET OR SETS OF REQUIREMENTS INTO ONE OR MORE FEASIBLE DESIGN CONFIGURATIONS SIZED TO MEET THE REQUIREMENTS AND OPTIMIZED FOR END USE BY VARIOUS TRADE STUDIES. IT MAY INCLUDE TRADING ONE CONFIGURATION AGAINST ANOTHER - USUALLY CALLED POINT DESIGNS. IT IS THE EARLIEST DESIGN RESPONSE TO SPECIFIC REQUIREMENTS. ITS ORIENTATION IS BASICALLY TOWARDS VEHICLE DESIGN.

ALL AIRCRAFT DESIGNERS USE A SIMILAR APPROACH TO THE CONCEPTUAL DESIGN PROCESS.

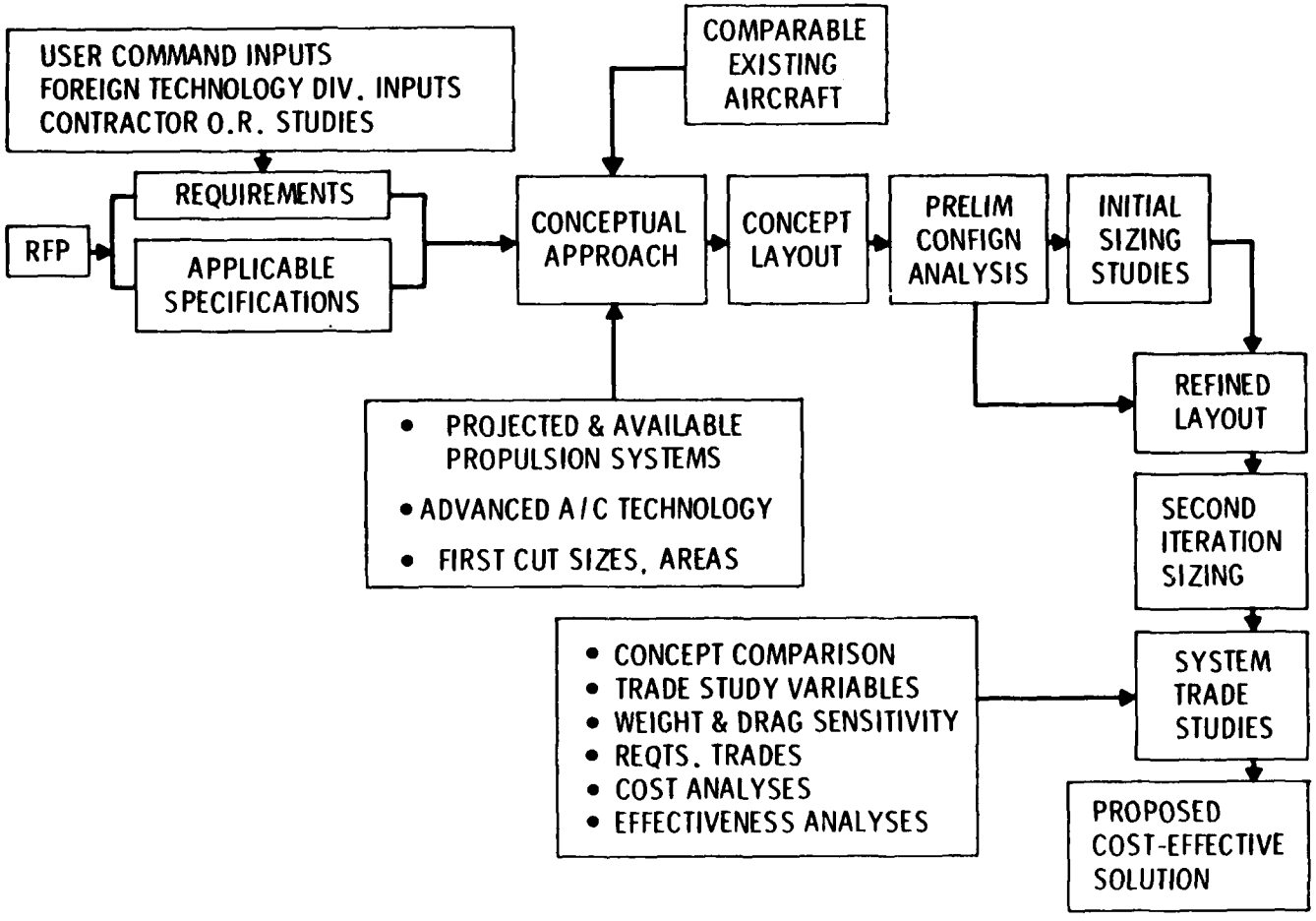
"CONCEPTUAL DESIGN" IS DEFINED

- SYSTEMIZED WORK PROCESS
- REQUIREMENTS → FEASIBLE CONFIGURATION
- SIZED
- OPTIMIZED BY TRADES (POINT DESIGNS)
- EARLIEST RESPONSE TO SPECIFIC REQUIREMENTS
- PARAMETRIC
- BASIC ORIENTATION → VEHICLE DESIGN

ALL A/C DESIGNERS USE A SIMILAR APPROACH

AT FRC, DATA FROM VARIOUS SOURCES ARE ASSEMBLED TO DEVELOP ONE OR MORE CONCEPTUAL APPROACHES FOR WHICH CONCEPT LAYOUTS OR ARRANGEMENT DRAWINGS ARE MADE. AFTER PERFORMING CERTAIN ANALYSES FOR DEVELOPING INPUT DATA, A COMPREHENSIVE AIRCRAFT SIZING AND TRADE-STUDY PROGRAM IS EXERCISED TO ELIMINATE UNLIKELY SOLUTIONS AND TO SELECT LIKELY CANDIDATES FOR ITERATION AND REFINEMENT. SYSTEM LEVEL TRADE STUDIES ARE PERFORMED ON ALL VIABLE CANDIDATES TO PROPOSE THE MOST COST EFFECTIVE RESPONSE TO THE REQUIREMENTS.

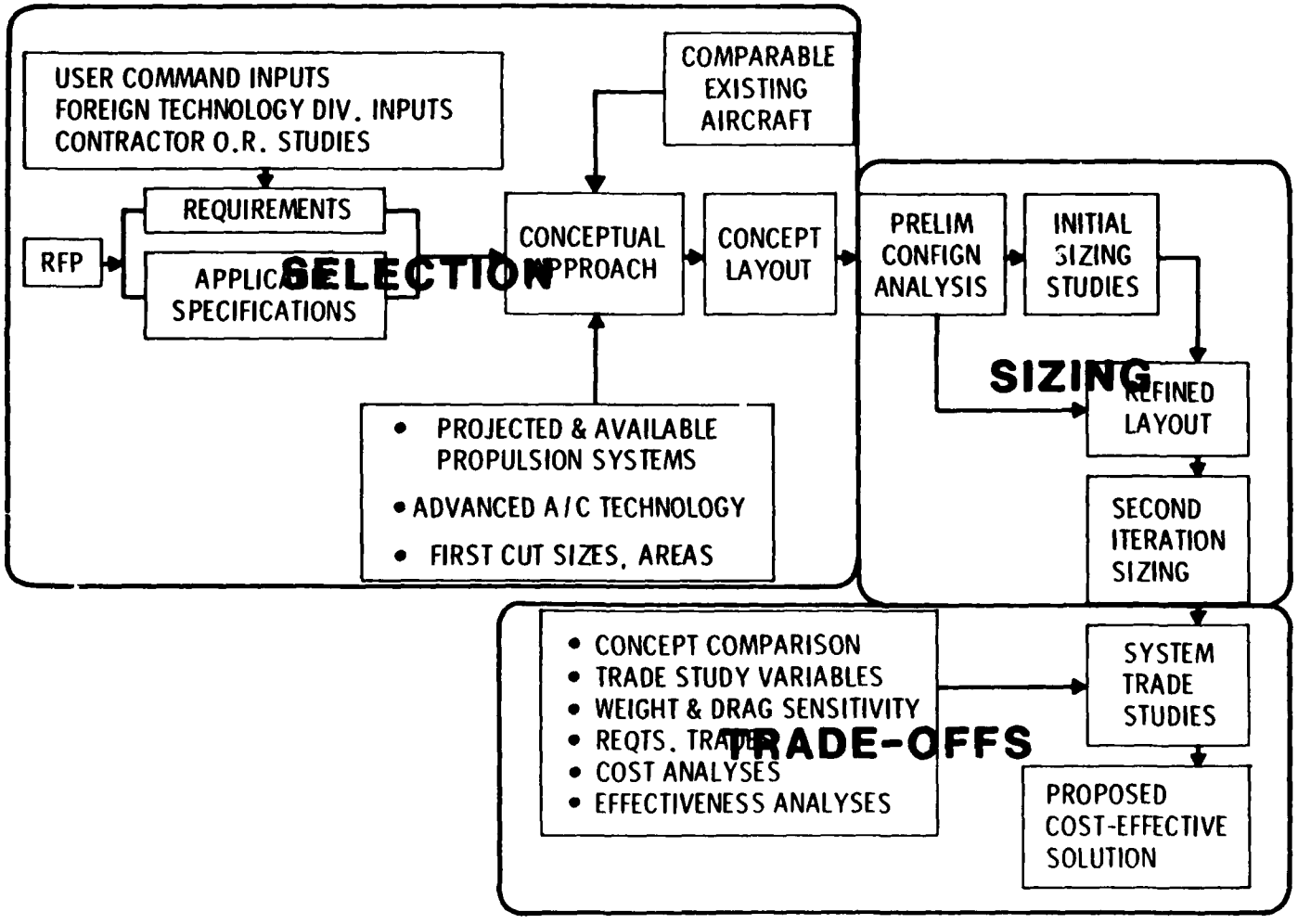
ALL AIRCRAFT DESIGNERS USE A SIMILAR APPROACH



OVERLAY

THE PROCESS PREVIOUSLY SHOWN IS ROUGHLY DESCRIBED IN THREE GENERALIZED PROCESS STEPS: SELECTION, SIZING AND TRADE STUDY.

ALL AIRCRAFT DESIGNERS USE A SIMILAR APPROACH

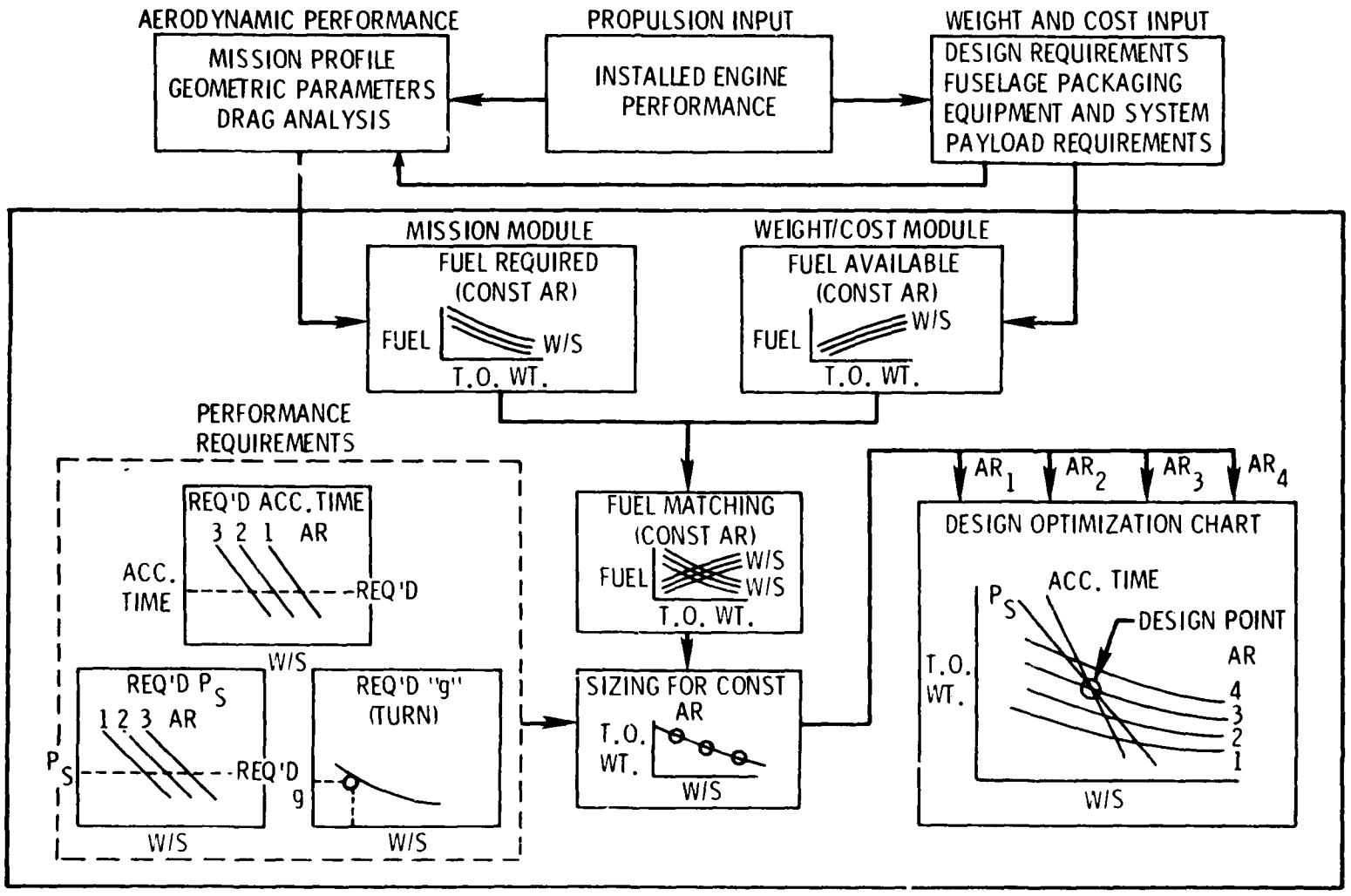


FRC PROCESS IS PARAMETRIC & COMPUTERIZED

FRC'S A/C SIZING AND TRADE-STUDY PROCESS IS HEAVILY COMPUTERIZED AND OPERATES TO EXAMINE A WIDE RANGE OF PARAMETERS. IT IS DEPENDENT ON THREE SUB-MODULES FOR SETTING AERODYNAMIC, PROPULSION AND WEIGHT/COST PARAMETERS, AND SIZES AIRCRAFT BY OVERLAPPING MISSION FUEL REQUIREMENTS FROM A MISSION MODULE WITH FUEL AVAILABLE CALCULATIONS FROM THE WEIGHT-COST MODULE. THE MATCH POINTS ON FUEL SET THE AIRCRAFT SIZES. THE PARAMETRIC SIZING INFLUENCES OF FACTORS SUCH AS ASPECT RATIO, HERE SHOWN AS AR, WING LOADING SHOWN AS WS, AND OTHERS, CAN BE DETERMINED. SUBSIDIARY CALCULATIONS TO SET MINIMUM (OR MAXIMUM) REQUIREMENTS FOR THESE PARAMETERS ARE INCLUDED. THE END RESULT IS AN OPTIMIZED POINT DESIGN CAPABLE OF SATISFYING ALL REQUIREMENTS.

THE NEXT VU-GRAPH SHOWS THIS FUEL MATCHING/AIRCRAFT SIZING RELATIONSHIP IN MORE DETAIL ----------

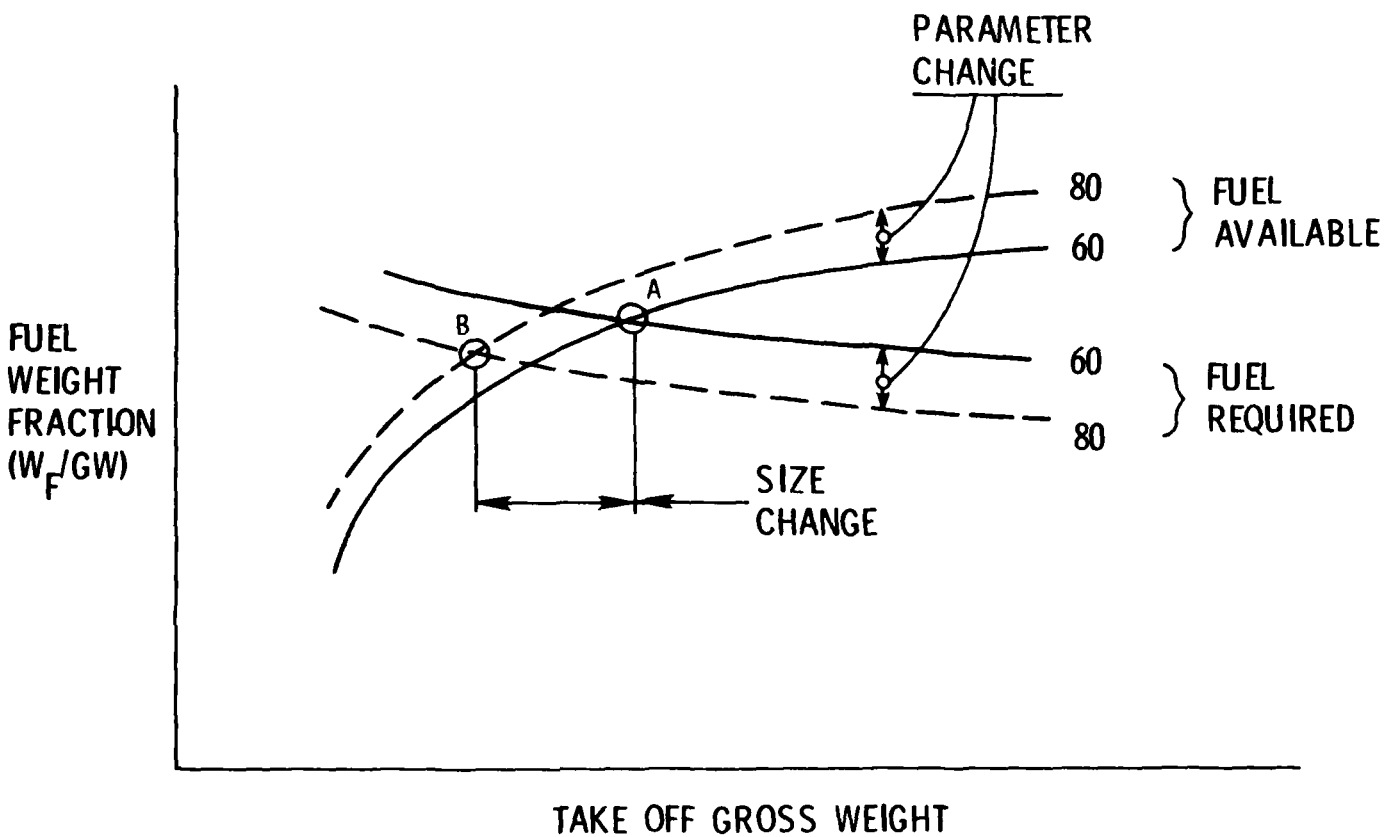
FRC PROCESS IS PARAMETRIC & COMPUTERIZED



FRC SIZING PROCESS IS USED FOR TRADE-OFFS

---- AND ALSO SHOWS HOW AIRCRAFT SIZE IS INFLUENCED IN THE TRADE STUDIES. A WING LOADING TRADE STUDY IS ILLUSTRATED WHERE THE ORIGINAL MATCH OF THE FUEL REQUIRED TO MAKE THE REQUIREMENTS WITH THE FUEL WHICH CAN BE MADE AVAILABLE IN A PROPERLY WEIGHT ANALYZED AIRPLANE PRODUCES A FINITE TAKE-OFF GROSS WEIGHT OR AIRPLANE SIZE FOR A WING LOADING OF 60 LB/FT^2 - POINT A. THE CHANGE TO A WING LOADING OF 80 LB/FT^2 PRODUCES A SMALLER AIRPLANE WITH LESS FUEL - POINT B. ALL TRADE PARAMETERS HAVE SUCH AN INFLUENCE AND CAN BE SIMILARLY ENCOMPASSED.

FRC SIZING PROCESS IS USED FOR TRADE-OFFS

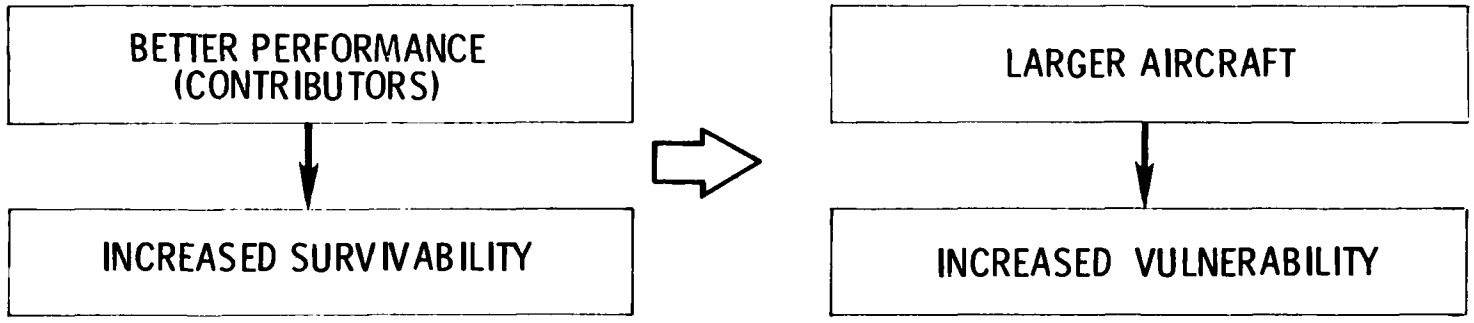


PROCESS CAN HANDLE S/V TRADES

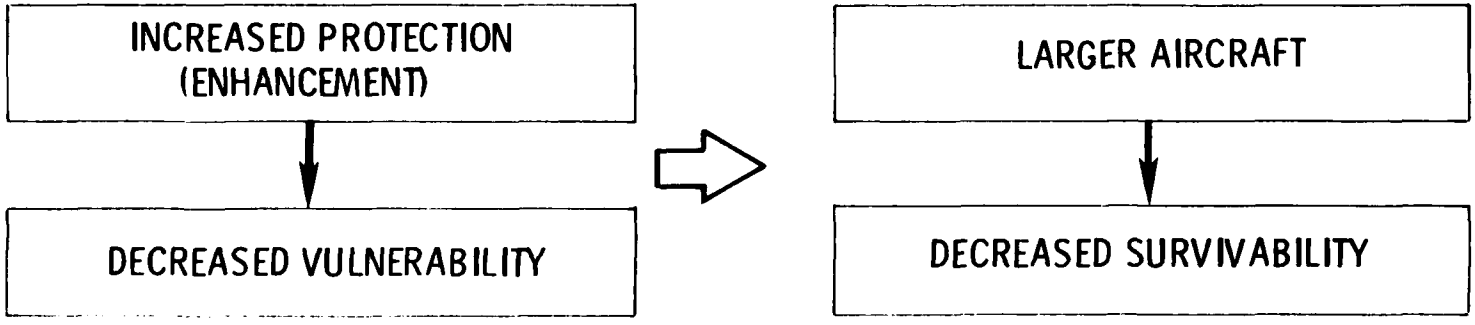
S/V IS NO EXCEPTION. THE PROCESS CAN HANDLE IT IF THE PROPER FORMULATIONS CAN BE INTRODUCED. IT CAN STUDY BETTER PERFORMANCE WHICH YIELDS INCREASED SURVIVABILITY BUT HAVING THE PROPERTY OF CAUSING LARGER AIRCRAFT WITH INCREASED VULNERABILITY VERSUS ENHANCING THESE TO REDUCE VULNERABILITY WHICH ALSO INCREASES SIZE AND REDUCES SURVIVABILITY. ALL COMBINATIONS CAN BE TRADE-STUDIED. THE MISSING METHODOLOGIES FOR ACCOMPLISHING THIS HAVE BEEN DEVELOPED UNDER THE CONTRACT IN A GENERIC, PORTABLE SENSE. SUPPORTING GEOMETRIC AND WEIGHT ANALYSIS METHODOLOGIES ARE INCLUDED.

THE NEXT TWO VU-GRAPHS SHOW TWO EXAMPLES OF HOW THE METHODOLOGY WAS DEVELOPED. THIS IS ILLUSTRATIVE ONLY OF WHAT WAS INCLUDED IN TASK II, THE BULK OF THE CONTRACT WORK.

PROCESS CAN HANDLE S/V TRADES



OR



S/V METHODOLOGY FOR CONCEPTUAL DESIGN HAS BEEN DEVELOPED (CREW SYSTEM)

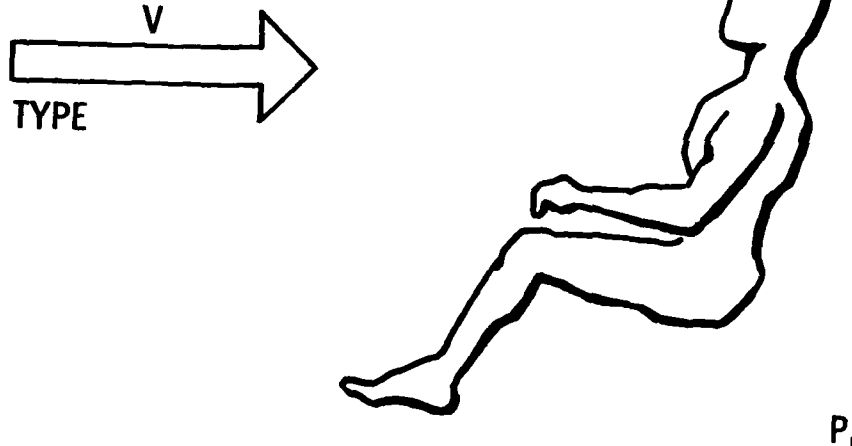
THE CREW STATION VULNERABILITY ASSESSMENT METHODOLOGY FOR AP PROJECTILES WAS DEVELOPED FOR VARIOUS TYPES OF PROJECTILES AND VARYING PROJECTILE VELOCITIES. A 95 PERCENTILE MAN WAS USED. KILL DATA CAME FROM FRC TECHNICAL REPORTS AND VARIES AS SHOWN IN THE GRAPH AT THE LOWER RIGHT.

JTCG/AS PENETRATION EQUATIONS DETERMINE THE RESISTANCE TO THE PROJECTILE'S PENETRATION, AND THE STANDARD REDUCED VELOCITY EQUATION, WITH A FACTOR FOR BLUNT PROJECTILES, WAS USED TO DETERMINE THE STRIKING VELOCITY AT THE CREW MEMBER.

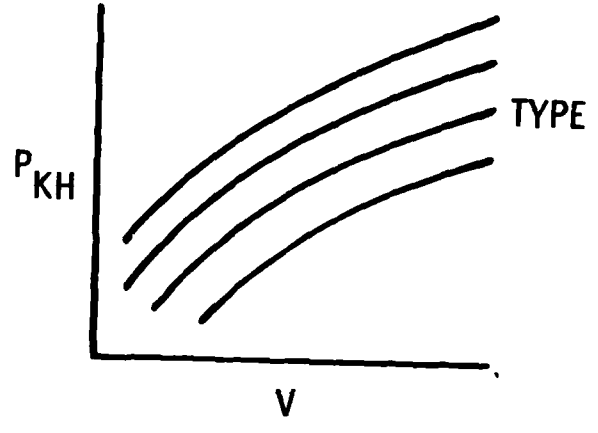
FOR THE FUEL SYSTEM, THE FUEL TANKAGE SPECIFICALLY - - - - -

S/V METHODOLOGY FOR CONCEPTUAL DESIGN HAS BEEN DEVELOPED

CREW SYSTEM



A_P = 95% ILE



- $A_V = P_{KH} \times A_P$
- JTCG/AS PEN. EQUAT'NS
- $V_R^2 = (V_S^2 - V_{50}^2) \times F_{BLUNT}$

S/V METHODOLOGY FOR CONCEPTUAL DESIGN HAS BEEN DEVELOPED (FUEL SYSTEM)

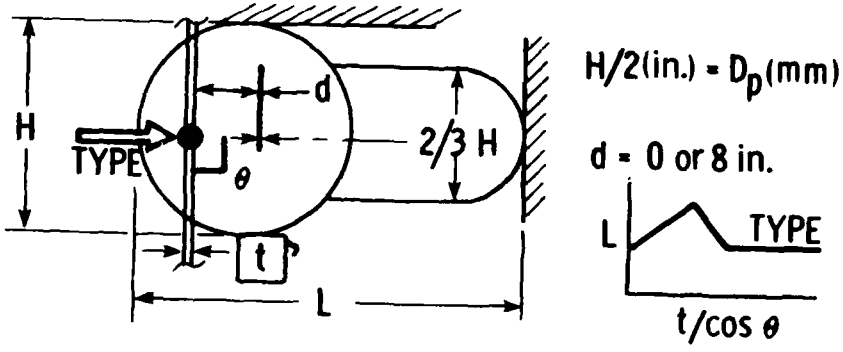
- - - - THE VULNERABILITY ASSESSMENT METHODOLOGY TO A POINT-DETONATING, HIGH-EXPLOSIVE PROJECTILE IS ILLUSTRATED. THE SURFACE SKIN IS AT THE STRIKING POINT AND CONCEPTUAL LOCATIONS OF THE FUEL BOUNDARIES ARE SHOWN IN CROSS-HATCH. THE PENETRATION DEPTH (D) AND THE FIREBALL SHAPE (H AND L) ARE AS DETERMINED IN FRC TECHNICAL REPORTS, FIREBALL DIAMETER H (IN INCHES) AS A FUNCTION OF THE PROJECTILE DIAMETER D_P (IN MM), AND FIREBALL LENGTH AS A FUNCTION OF THE SKIN THICKNESS AND OBLIQUITY. NOT SHOWN, IS A LINEAR DEPENDENCE ON STRIKING VELOCITY.

THIS CASE IS AN UNPROTECTED (I.E., NOT ENHANCED) CASE FOR THE WETTED AREA OF THE FUEL TANKAGE AND FOR AN INTEGRAL OR BLADDER CELL. IT IS ASSUMED THAT THE PROJECTILE FRAGMENTS WILL CAUSE LEAKS AND A FIRE OCCURS ($P_F = 1.0$) IF THE FIREBALL TOUCHES THE LEAKING CELL WALL. IF THE PENETRATION IS INTO THE FUEL CELL, NO FIRE OCCURS ($P_F = 0$).

THE GEOMETRICAL DEVELOPMENTS WHICH ARE PART OF THE METHODOLOGY ARE MEANS OF PREDICTING THE PRESENTED AREA OF THE WETTED FUEL CELL (A_p) AND THE HEIGHT OF THIS REGION (H).

S/V METHODOLOGY FOR CONCEPTUAL DESIGN HAS BEEN DEVELOPED

FUEL SYSTEM



- UNPROTECTED / WETTED – BLADDER
- P_F = 1.0 (INSIDE FUEL = 0)
- REQUIRE [A_P] WETTED AND WETTED [h]

METHODOLOGY VALIDATED ON A-10A & OV-10A

TASK III OF THE CONTRACT REQUIRED SAMPLE CASES TO BE RUN SO THAT THERE WAS ASSURANCE OF THE WORKABILITY OF THE TASK II METHODOLOGY AND TO DISCOVER ERRORS, OMISSIONS AND IMPROVEMENTS REQUIRED. THE CONTRACTING AGENCY SELECTED THE CASES AND CONDITIONS. VULNERABLE AREA RESULTS FOR BOTH THE A-10A AND OV-10A AIRCRAFT WERE CALCULATED IN THE ENHANCED AND UNENHANCED STATE FOR VARIOUS THREATS. THE WEIGHT INFLUENCES OF ENHANCEMENTS AND THE AIRCRAFT SIZING EFFECTS WERE INCLUDED.

THIS TABLE PROVIDES ONE SET OF RESULTS FOR THE A-10A AIRPLANE. THE "ENHANCED A-10A" COLUMN RESULTS OF THE SAMPLE CASES CAN BE COMPARED TO THE "ACTUAL VALUES" COLUMN WHICH ARE THE A-10A DETAILED ANALYSIS VALUES. EXCEPT WHERE THERE WERE SIGNIFICANT DIFFERENCES IN GROUND RULES IN THE TWO ANALYSES THE AGREEMENT IS QUITE GOOD.

METHODOLOGY VALIDATED ON A-10A & OV-10A

VIEWING ASPECT	THREAT	VELOCITY FT/SEC	VULNERABLE AREAS – SQ. FT.		
			ENHANCED A-10A	UNENHANCED A-10A	ACTUAL VALUES
SIDE	3	1000	1.22	11.32	1.12
		2500	2.94	14.98	2.65
	8	–	6.08	13.20	NOT REQ'D
FRONT	4	1500	2.64	2.95	1.79
TOP	7	1000	189.32	185.58	190.33
BOTTOM	5	1000	76.50*	139.81	1.53*
		2500	18.07*	126.89	1.29*

*A-10A PROGRAM VULNERABILITY GROUND RULES DIFFER FROM CRITERIA EMPLOYED

POSITIVE RESULTS

THE CONTRACTED STUDY HAS DEFINED THE ROLE OF THE S/V ANALYST IN THE CONCEPTUAL DESIGN PROCESS. IT IS SHOWN THAT S/V CAN BE MADE AN INTEGRAL PART OF THE PROCESS BOTH BY INFLUENCING THE SIZING ASPECTS AND BY INCLUSION IN THE TRADE-STUDY ASPECTS. A METHODOLOGY HAS BEEN DEVELOPED WHICH CAN SERVE AS A GENERIC MODEL AND IT INCORPORATES THE NECESSARY GEOMETRICAL/WEIGHT PREDICTION DEVELOPMENTS. THE METHODOLOGY IS COMPLEX AND REQUIRES COMPUTERIZATION.

IT WAS ALSO NOTED IN THE STUDY THAT THE GRAPHICS CAPABILITIES INHERENT IN CURRENT CAD/CAM AND ICAD DEVELOPMENTS ADD A NEW DIMENSION TO THE PROBLEM OF INCORPORATING S/V IN THE CONCEPTUAL DESIGN PROCESS. THEORETICAL FORMULATIONS WILL BE REPLACED BY MEASUREABLE, PICTORIAL REPRESENTATIONS.

POSITIVE RESULTS

- S/V CAN BE INCORPORATED
  - SIZING
  - TRADE STUDY
- METHODOLOGY AS MODEL
- DEFINITIVE GEOMETRICAL DEVELOPMENTS
- COMPLEX/COMPUTERIZE
- CAD/ICAD ADDS NEW DIMENSION

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