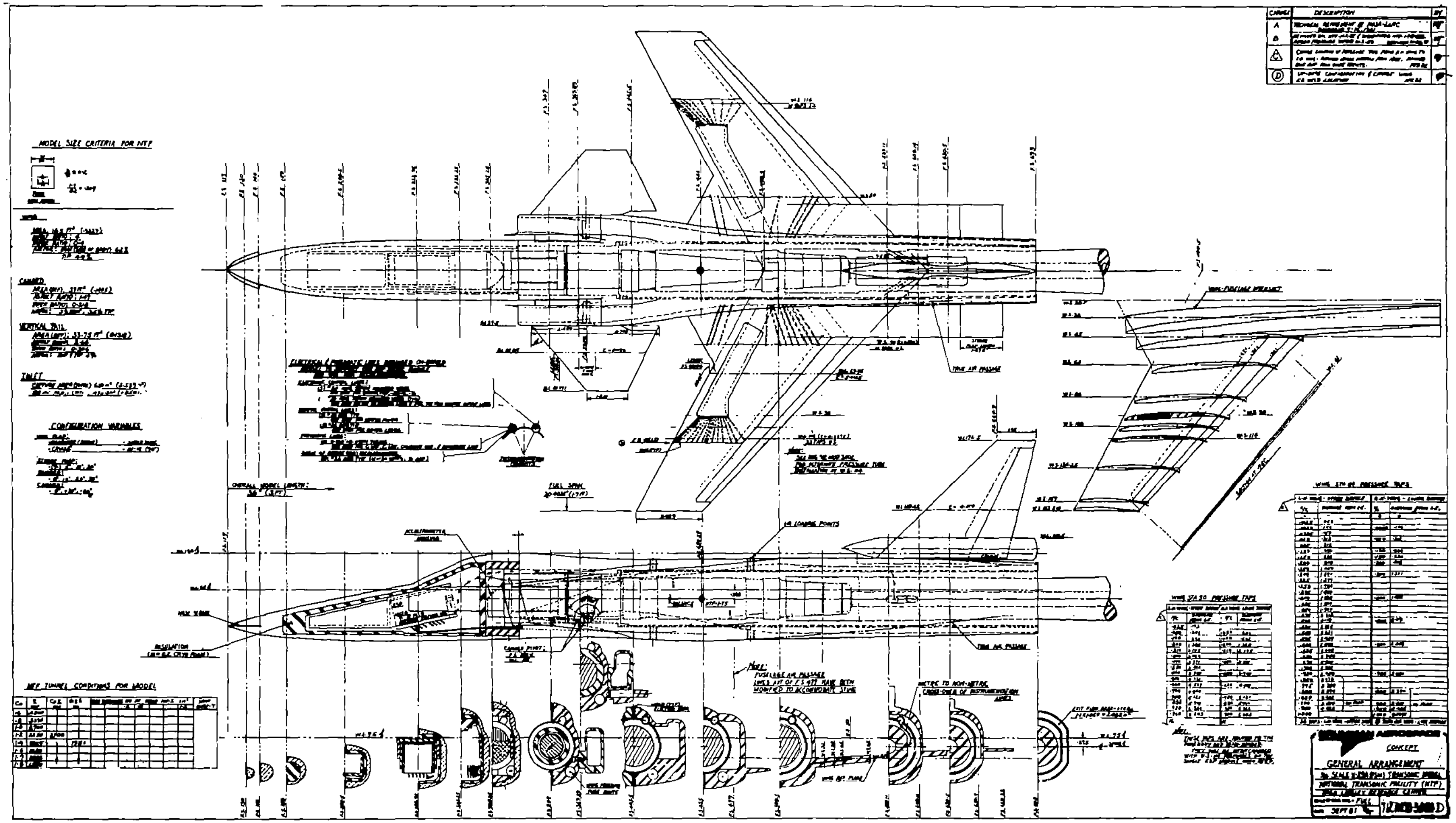
PART II

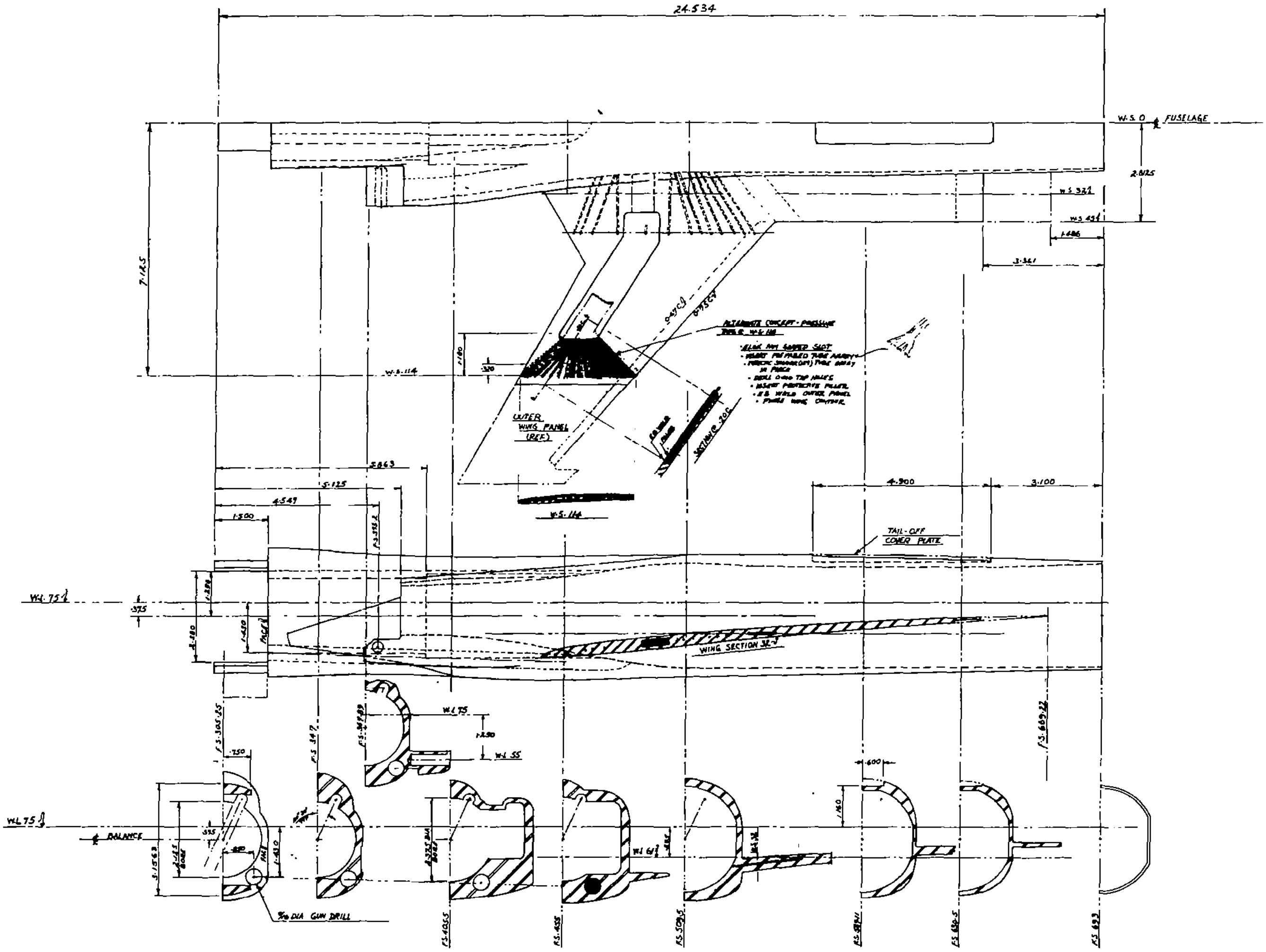
DESIGN AND FABRICATION CONCEPT

E. Toscano

The first concept of this drawing was done in September 1981 to determine if a small model to fit the NASA Langley sizing criteria could accommodate the aerodynamic and mechanical requirements prescribed in Part I of this presentation. For a model wing span of 1.7 ft (and a length of 3 ft), the model is 6.25 percent (1/16 scale). The results were encouraging enough for Grumman to request, in early December 1981, that the design concept be refined at NASA Langley, where up-to-date cryogenic model design information was available. This working session was completed by a Grumman designer by mid-December. In its present form, the concept will be the basis for any continued effort.


MODEL SIZE CRITERIA FOR NTF
CANARD
VERTICAL TAIL
AREA (WFT): 33.75 FT²
INLET
CONFIGURATION VARIABLES
NTF TUNNEL CONDITIONS FOR MODEL
OVERALL MODEL LENGTH: 36" (3FT)
FULL SPAN
TRUE AIR PASSAGE
ACCELEROMETER
INSULATION
NOTE: FUSELAGE AIR PASSAGE LINES AFT OF F.S. 977 HAVE BEEN MODIFIED TO ACCOMMODATE STING
METRIC TO NON-METRIC CROSS-OVER OF INSTRUMENTATION LINES
WING STA 50 PRESSURE TAPS
CHANGE
DESCRIPTION
BY
A
B
C
D
CONCEPT
GENERAL ARRANGEMENT
NATIONAL TRANSONIC FACILITY (NTF)
FULL
3 SEPT 81
D

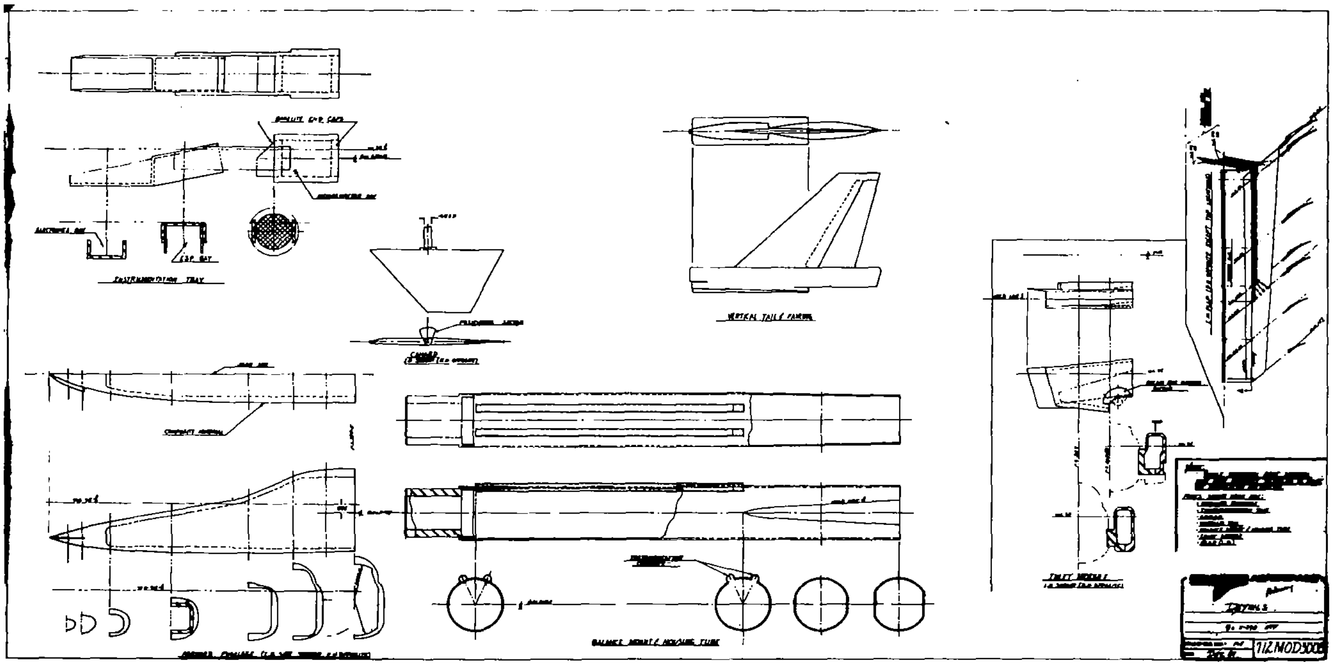
This drawing is a preliminary detail of the major model structure which embodies the monocoque concept. The purpose of the drawing is to give the visibility needed to develop a first-cut design and fabrication cost.



NOTE:
THIS DRAWING IS FOR ESTIMATING PURPOSES ONLY. NOT FOR FABRICATION!

- LEFT HAND PART SHOWN. R.H OPPOSITE EXCEPT FOR DETAILS OF PRESSURE TAP LOCATIONS (see [illegible])
- ALL INTERNAL MACHINING (except [illegible] balance [illegible] & balance housing [illegible]) GUN DRILLING, ELOXING AND ROUTING OF PRESSURE LINES TO BE COMPLETELY FINISHED BEFORE WELDING TWO HALVES AND WELDING OVERSIZE OUTER WING PANELS IN PLACE.
- OUTER WING PANEL PRESSURE TUBES AND COVER PLATES TO BE INSTALLED BEFORE FINAL CONTOURING
- SEE DWG 7H MOD 3000 C FOR MORE DETAIL ASSESSMENT OF OUTER WING PANEL INSTRUMENTATION

For the same purpose of developing first-cut model costs, this drawing shows all the other detail parts in preliminary form.



As a result of the three previous drawings, the model hardware and pressure instrumentation features were developed into this chart for ready reference in continued discussion and in any further detail design.

MODEL CONCEPT FEATURES

- MONOCOQUE STRUCTURE
  - INTEGRAL WING-BODY, 64% LENGTH
  - ONE PIECE INSULATED FWD FUSELAGE, 36% LENGTH } MINIMIZES MECHANICAL JOINTS
  - EB WELD OF FUSELAGE
  - EXTERNAL MECHANICAL JOINTS: FWD FUSELAGE, FLAPS, VERTICAL TAIL, CANARDS, INLETS
  - SERVICEABLE INSTRUMENTATION TRAY UPON REMOVAL OF FWD FUSELAGE SHELL
- WING PRESSURE TAPS (75)
  - ALL PRESSURE ROUTING IS INTERNAL TO MAIN WING VIA EDM/EB WELD FOR BETTER LINE FIDELITY (FLAP PRESSURES MUST BE SURFACE ROUTED)
  - TAP LOCATIONS
    - W.S. 50 LEFT WING: 16 TOP + RIGHT WING: 11 BOTTOM = 27
    - W.S. 114 LEFT WING: 33 TOP + RIGHT WING: 15 BOTTOM = 48
  - ONE 48 PORT ESP SERVICING EITHER W.S. 114 OR W.S. 50
- CANARDS AND VERTICAL TAIL
  - REPLACEABLE WITH OFF BLOCKS
  - NO CANARD REMOTE CONTROL
- TOLERANCES AND FINISH
  - HAND REFINEMENT ON WING L.E. (10% CHORD) TO .001 INCH
  - REMAINDER OF WING AND CANARD: ± .004 INCH } SURFACE FINISH 8-16 μINCH
  - FUSELAGE: .006 INCH
- BALANCE
  - PROPOSED 1.75" NTF BALANCE TO BE BUILT BY NASA LaRC

This chart provides the same ready reference for discussing electronic instrumentation. It is noted that the specific information contained here was a direct result of the December 1981 working session at NASA Langley.

INSTRUMENTATION

- INSTRUMENTATION TRAY CARRYING:
  - 48 PORT ESP SENSOR W/DIGITAL ADDRESS PC BOARD
  - AOA SENSOR
- ELECTRICAL AND PNEUMATIC LINES FOR ABOVE UNITS
  - ELECTRONIC CONTROL LINES:

    (5) #20 AWG TEFLON INSULATED WIRE (TIW) - ONE EACH FOR GROUND +12V, -12V, $+V_S$, $-V_S$

    (8) #24 AWG TIW - ONE EACH FOR SIX ADDRESS LINES AND ONE EACH FOR THE TWO MODULE OUTPUT LINES
  - HEATER CONTROL LINES:

    (2) #20 AWG TIW - ONE EACH FOR HEATER POWER
    (3) #26 AWG TIW - ONE EACH FOR SENSOR LEADS
  - PNEUMATIC LINES

    (4) 0.060 I.D. NYLON TUBING - ONE EACH FOR C_1 LINE, C_2 LINE, CALIBRATE LINE, AND REFERENCE LINE
  - AOA SENSOR (ACCELEROMETER)

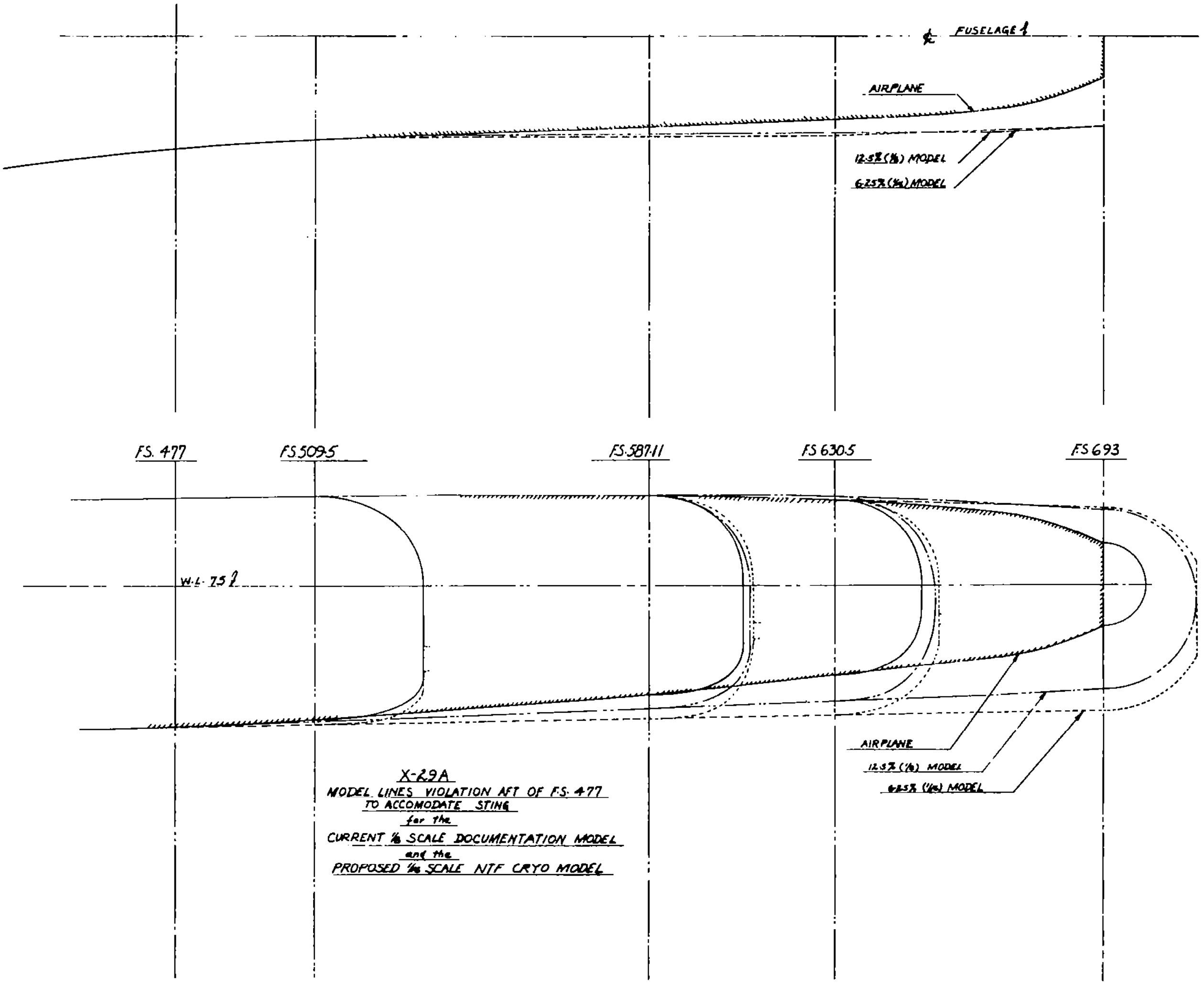
    (10) #26 AWG TIW (15 OR 20 WATTS; ½ AMP)
- THERMOCOUPLES - INTERNAL FUSELAGE: (3) TYPE K - CHROMEL/ALUMEL
- 1.75" NTF BALANCE: NF = 2500#, AF = 250#, SF = 1000#, PM = 5000 IN-LBS., YM = 2000 IN-LBS., RM = 1500 IN-LBS.

Since the X-29A air passage lines are frozen, this chart of configuration variables is limited to the preliminary selection of control surface position.

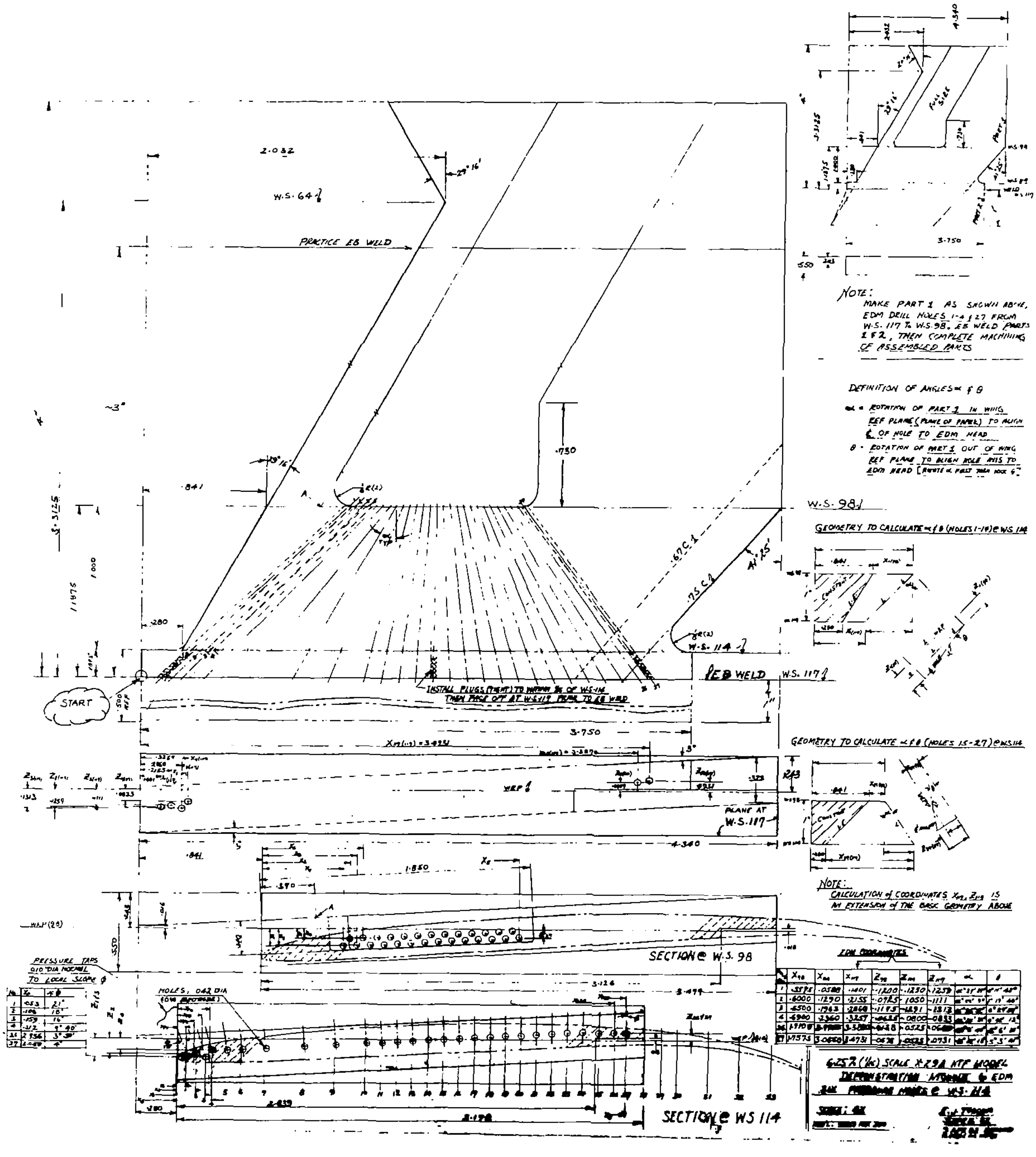
CONFIGURATION VARIABLES

- WING FLAPS: MANEUVER/CRUISE/SUPERSONIC/HI-α
- STRAKE FLAPS: (+/-) 5^{o}, 10^{o}, 30^{o}
- CANARDS: 0^{o}, $+30^{o}$, -60^{o} (ANY COMBINATION L&R)
- RUDDER: 0^{o}, 10^{o}, 20^{o}, 30^{o} (T.E. DEFLECTED RIGHT)
- VERTICAL TAIL, CANARDS, AND FLAP HINGE FAIRING: ON AND OFF

A comparison between aft airplane and NTF model air passage lines shows how the airplane lines must be modified to accommodate the model sting support. As a reference, the existing 12.5-percent scale Documentation Model is also shown. Since the NTF model aerodynamic loading can be relatively much higher than the Documentation Model (tested in air tunnels), the relatively larger sting for the NTF model causes the greater model lines violation.



This is a detail of a portion of the X-29A model wing where the EDM process is applied to drill pressure passages in the middle of the wing for pressure orifices at wing station 114. The detail emphasizes the need for calcuation accuracy of the layout geometry to start an EDM drilled hole in one place and emerge in another place with virtually no deviation beyond a few thousanths of an inch. Before such an attempt to drill high-density pressure passages is started, the mathematics and machine operation set-up must be thoroughly checked and double-checked. (All specimens were fabricated by the Grumman PDOC organization under the direction of Rudy Ferro.)

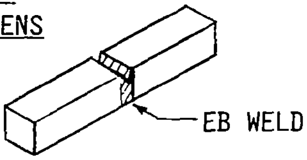


Presented here are the results of standard configured Charpy and tensile specimens of electron-beam-welded Vascomax material. Some of the Charpy specimens and all of the tensile specimens were welded in the as-received state, re-solution heat treated, and aged. The other Charpy's (5, 6, and 7) were only aged as shown. Those that were only aged had a reduced Charpy V-notch value, which shows that the re-solution heat treat cycle to improve grain structure should be the accepted process to improve material toughness. It is noted at this time that the lowest Charpy value of 17 ft-lb in specimens 1 to 4 compares favorably with those of the NASA Langley unwelded specimens recently tested.

RESULTS OF GRUMMAN EB WELDED VASCO MAX 200 TEST SPECIMENS

PERFORMED AT NASA LANGLEY ON MAY 4-5, 1982

CHARPY
SPECIMENS

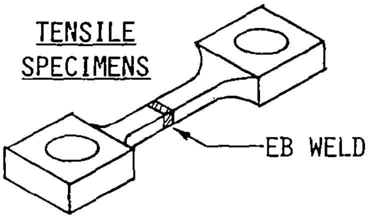


IMPACT TEST REPORT

MACHINE - SATEC SI-1C, CAPACITY: 240 FT-LB
IMPACT VELOCITY: 17 FT/SEC
SPECIMEN/TYPE: CVN SIZE: STANDARD

SP. NO.	TEST TEMP °F	IMPACT VALUE (FT-LBS)	LATERAL EXPANSION (MILS)	COMMENTS
1	-320	21	6	-ANNEALED @ 1500°F FOR ONE HOUR,** AIR COOLED -AGED @ 900°F FOR THREE HOURS,** AIR COOLED
2	-320	17	4	
3	-320	20	3	
4	-320	20	5	
5*	-320	5	7	AGED @ 900°F FOR THREE HOURS,** AIR COOLED
6	-320	14	3	
7	-320	15	3	
				*DEFECT IN WELD HOLE **IN AIR FURNACE

TENSILE
SPECIMENS



SP.	TEST TEMP °F	FAILURE LOAD LB	NECK DOWN INCHES	FAILURE INCHES
A	-302	13000	.13	.20
B	-302	12790	.125	.198
C	-302	12720	.128	.206

NOTE:

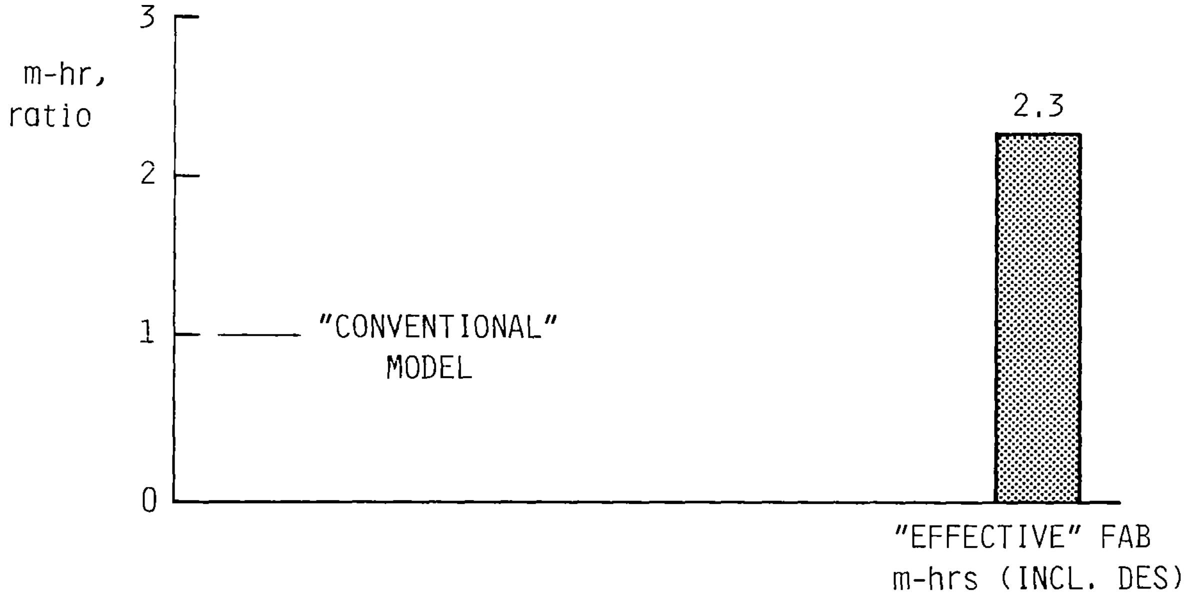
1. SPECIMENS ANNEALED @ 1500°F FOR ONE HOUR,** AIR COOLED AND AGED @ 900°F FOR 3 HOURS, AIR COOLED.
2. SPECIMENS WERE PREDICTED TO BREAK AT 12,000 LB BASED ON 250,000 PSI ULTIMATE STRESS AT ~ -300°F AND MIN-CROSS SECTION OF .248X.1935 SQUARE INCHES.

PART III

COST AND SCHEDULES

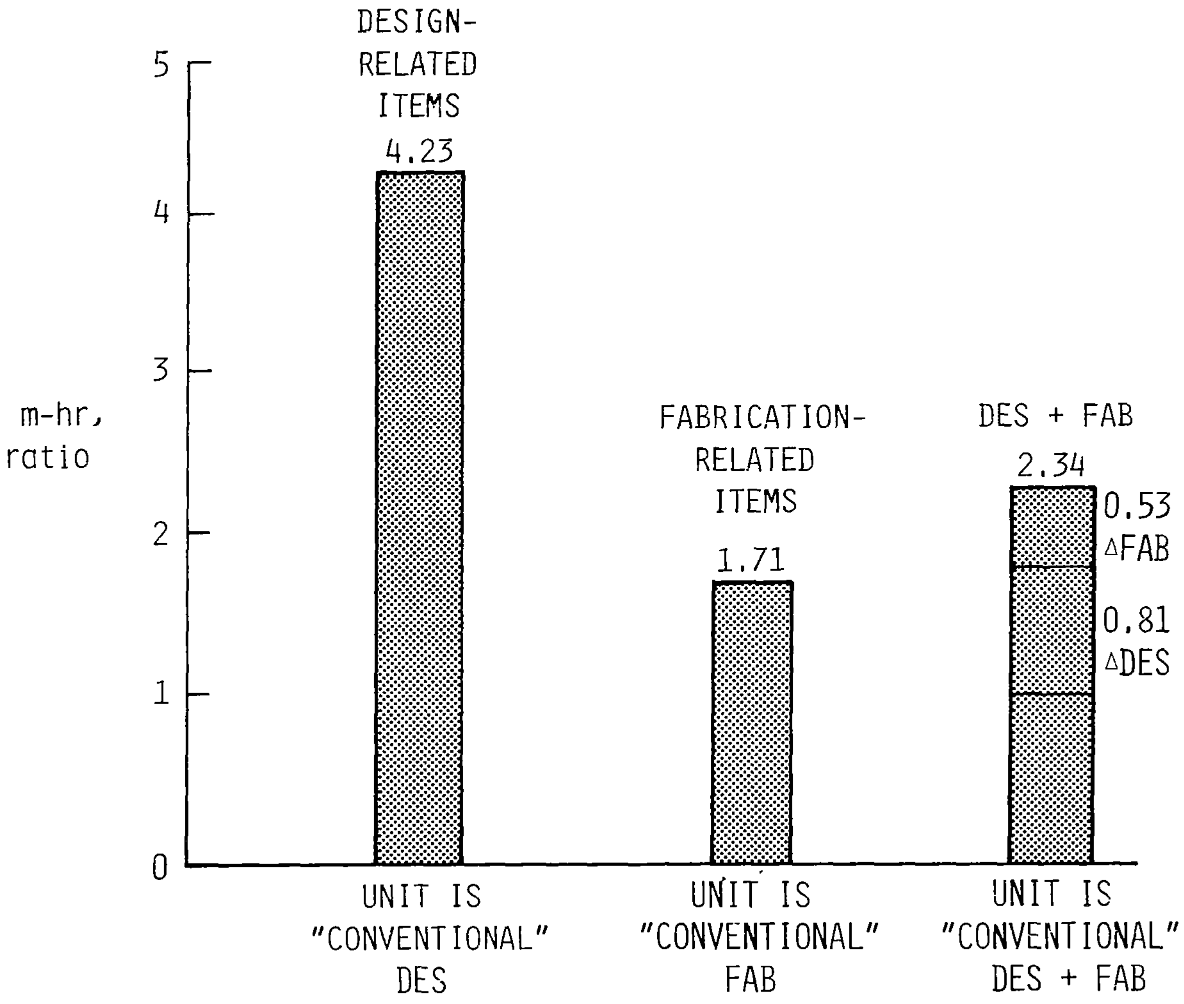
G. DaForno

On costs, we give first the 'bottom line'; that is, the answer to the question "How much more does this NTF model cost than the same-size 'conventional' model?" The best way to give the answer is in the form of man-hour ratios. (These man-hours are for design and fabrication; however, design hours cost considerably more (say, 1.375 times) than fabrication hours, and hence are not cost additive to fabrication hours. To get comparable man-hour ratios and cost ratios, the design man-hours have been translated into 'effective' fabrication hours by multiplying them by 1.375.)



RELATIVE COST OF DESIGN AND FABRICATION
OF X-29A 1/16 NTF MODEL (EST.)

The man-hour ratio can be broken down into the two traditional elements, design and fabrication, each given as a ratio to the corresponding 'conventional' effort. (We prefer a breakdown into two elements rather than four - design, fabrication, NC programming, and computer costs.) This figure shows the very considerable increase we envision in the design effort.



RELATIVE COST BROKEN DOWN INTO RELATIVE DESIGN
AND RELATIVE FABRICATION COSTS

Every cost estimate depends heavily on precisely what is costed and what ground rules are used. This chart spells out key information of this nature associated with the estimates of the previous charts. The estimate of the NTF model was considerably detailed, even if at a model concept level. The requirements set forth in LHB 8850.1, Wind Tunnel Model Systems Criteria (Langley Research Center, Sept. 1981), were addressed in intent but were not followed to the letter. These criteria were interpreted by Grumman's quality assurance and quality control disciplines, since a major airframe manufacturer would be conditioned in attitude by the tradition of full-scale production hardware.

GROUND RULES
FOR DES & FAB COST OF X29A 1/16 NTF MODEL

- CONVENTIONAL MODEL:
  - CONVENTIONAL SIZE FOR 8 FT TRANSONIC TUNNEL (USABLE ALSO AT HIGH α IN 7' x 10's)
  - MODERATE MAC RE, $\sim 3 \times 10^6$, STEEL WING
  - NO LE HAND REFINEMENTS, CURSORY INSPECTION
  - NO DEFLECTION TEST
  - COST IS STATISTICAL
- NTF MODEL
  - WORK PACKAGE FROM 'REQUIREMENTS' TO 'END PRODUCT'
  - END PRODUCT: COMPLETE MECHANICAL ASSEMBLY AT GRUMMAN READY FOR WIRE INSTALLATION & CALIBRATION AT NASA LaRC
  - COST ITEMS NOT INCLUDED
    - + VASCOMAX 200 (BUT ACCEPTANCE CERTS INCLUDED)
    - + STING & KNUCKLES (DES & FAB)
    - + ESP
    - + TRAVEL EXPENSES
  - COST ITEMS INCLUDED: FULL DOCUMENTATION OF EFFORT, SYSTEMATIC LIAISON WITH NASA LaRC & COST TRACKING
  - COST IS BUDGETARY ESTIMATE OF THE ITEM-BY-ITEM BUILD-UP TYPE
  - REASONABLY-DEFINED SCOPE OF 22 TASKS

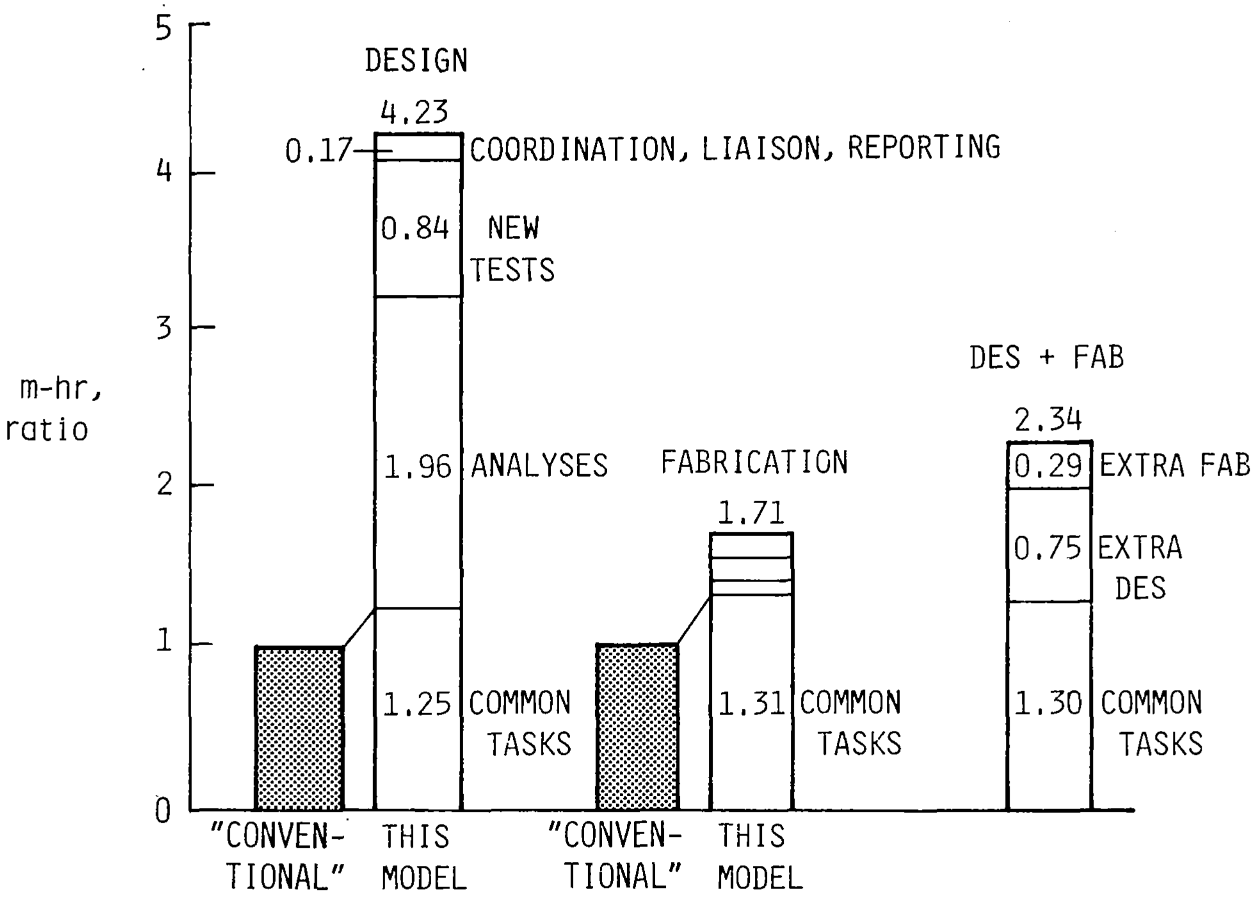
To cost out the NTF model, the design and fabrication effort was broken down into the work items listed in this figure. We separated the 'conventional' work items (requiring perhaps a small increase in effort in the case of the NTF model) from the new, NTF-required ones.

COST BUILD-UP
FOR DES & FAB OF THE NTF MODEL

	1.	CONVENTIONAL MODEL DESIGN AND STRESS ANALYSIS	DES
*	2.	SPECIALIST SUPPORT (STRESS AND THERMO)	↓
	3.	MODEL LINES	↓
*	4.	DETAILED STRESS ANALYSIS (INCL. FINITE ELEMENT ANAL.)	↓
*	5.	FRACTURE MECHANICS ANALYSIS	↓
*	6.	THERMAL ANALYSIS	↓
*	7.	DIVERGENCE ANALYSIS (COMPLETE MODEL SYSTEM)	↓
*	8.	FLUTTER ANALYSIS (THEORETICAL)	↓
*	9.	MATERIAL QUALITY ASSURANCE (CRYO USE) (INCLUDING CHARPY V-NOTCH AND TENSILE SPECIMENS)	FAB
	10.	FABRICATION AND INSTRUMENTATION (PRESSURE TAPS)	↓
	11.	INSTRUMENTATION (ELECTRONICS)	↓
	12.	INSPECTION	↓
*	13.	STATIC TEST FOR DEFLECTION	DES
*	14.	INFLUENCE COEFF. TEST	↓
*	15.	GROUND VIBRATION SURVEY & FLUTTER ANALYSIS	↓
*	16.	MODEL ENVELOPE	↓
*	17.	HAND REFINEMENTS	FAB
	18.	AERO TEST ENGINEERING (DES SUPPORT)	DES
	19.	AERO/L&D/PROJECT (DES SUPPORT)	↓
	20.	PROGRAM MGMT SERVICES	DES & FAB
*	21.	COORDINATION	↓
*	22.	LIAISON WITH NASA & REPORTS	↓

* SPECIAL REQ. FOR NTF

The work-item breakdown and the associated costs give some insight as to where the increased costs of the NTF model are accumulated. This is the point of this figure: in our estimates, a very large contributor to the increased design cost is detailed analysis and the tests in support of this analysis. This new activity is sufficient to shift the design versus fabrication balance on conventional models (1/4 versus 3/4) toward a different level (almost 1/2 veruss 1/2)/



This figure is a summary of the key points touched upon in the three parts of the paper (requirements, design and fabrication concept, and cost and schedule). (A detailed layout of the schedule, not presented, shows that at least 15 months are needed from the start of the concept work to delivery of the complete mechanical assembly of the model, ready for electronic instrumentation installation and test-site pretest activities.)

SUMMARY (X29A NTF MODEL CONCEPT)

REQUIREMENTS AND GUIDELINES/DESIGN LOADS

- ALL DATA ACCOMMODATED--AERO (HIGH SPEED AND HIGH α), LOADS, CORRELATION WITH 3 KEY TUNNELS
- MIN DESIGN LOAD AND LOWEST TEMPERATURES: $(c_N q)_{DES}$ = 2700 PSF, N = 1950#, T_t = 85 K
- MODEST q STUDY POSSIBLE (Δq = 1000 PSF, AT MDP)

DES AND FAB CONCEPT

- VASCOMAX 200
- MONOCOQUE CONSTRUCTION/EB WELDS/MIN MECHANICAL JOINTS
- EDM PRESSURE PASSAGES; 75 TAPS ACCOMMODATED ON WINGS
- DEMO OF EDM AND EB WELD FEASIBILITY
- INSULATED CAVITY FOR ESP (ESTIMATED HEATER POWER OK)

COST AND SCHEDULE

- DES AND FAB OF THIS NTF MODEL IS ~ 2.3 TIMES CONVENTIONAL
- DES IS ~ 4.2 TIMES CONVENTIONAL DES
- FAB IS ~ 1.7 TIMES CONVENTIONAL FAB (± 20%)
- COMPRESSED SCHEDULE: 15 MONTHS, INCLUDING CONCEPT