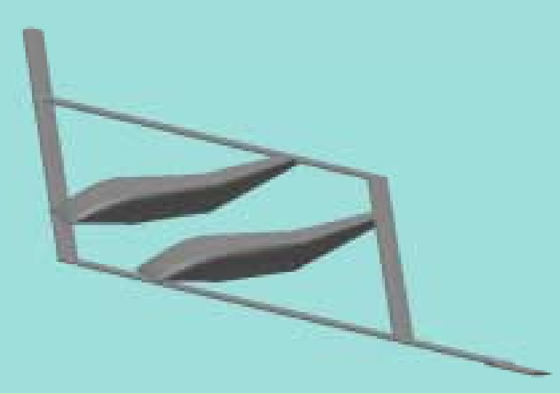
Nov 2002, Presentation UAV Workshop, Bath University

TOWARDS DESIGNING HIGH ASPECT RATIO HIGH ALTITUDE JOINED-WING SENSOR-CRAFT (HALE-UAV)



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BRISTOL, UK.

Report Documentation Page

Report Documentation Page	*Form Approved* *OMB No. 0704-0188*

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14. ABSTRACT

15. SUBJECT TERMS

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- The authors have pleasure in acknowledging helpful technical discussions with Dr. D. Multhopp, Dr Carl Tilmann, Dr. C. Jobe, Dr. W. Blake (all from US-AFRL), Dr. M. E. Palmer.

- Lastly, any opinions expressed are those of the author.

This Presentation

- Introduce HALE-UAV
- A Vision of Future – Sensor Craft Importance
- Joined-Wing Configs.
- 2-D Laminar Aerofoils
- Aspects of 3-D Design, different Swept Tips
- LE Suction Control, Elliptic loadings, Neutral Stab.
- CFD Checks
- Inverse 3-D Design Capabilities
- Intake Design – Preliminary Work
- Avenues for Further Work

Typical HALE Global Hawk

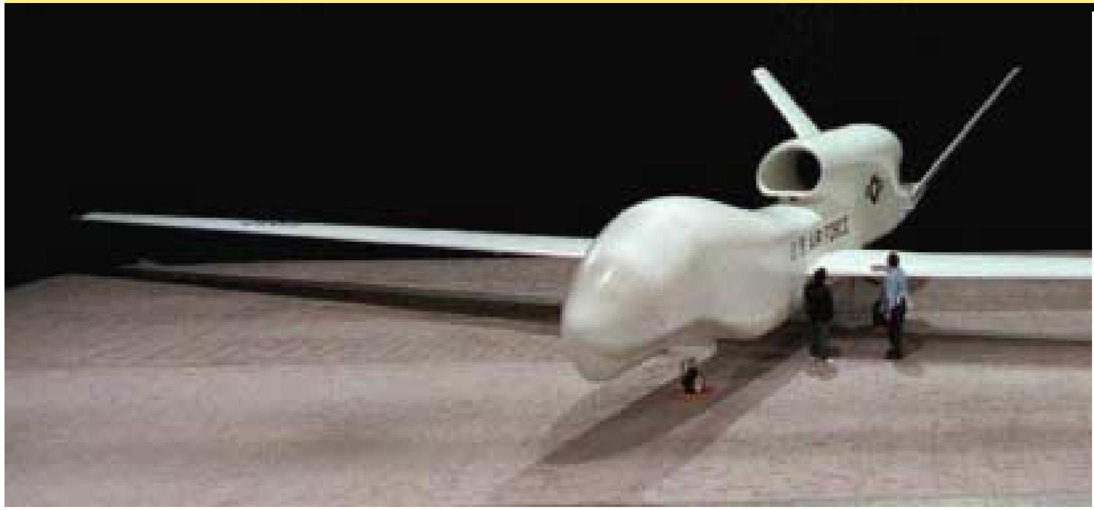
span: 116 ft, length 44 ft
light composites, aluminium fuselage, COST $10M

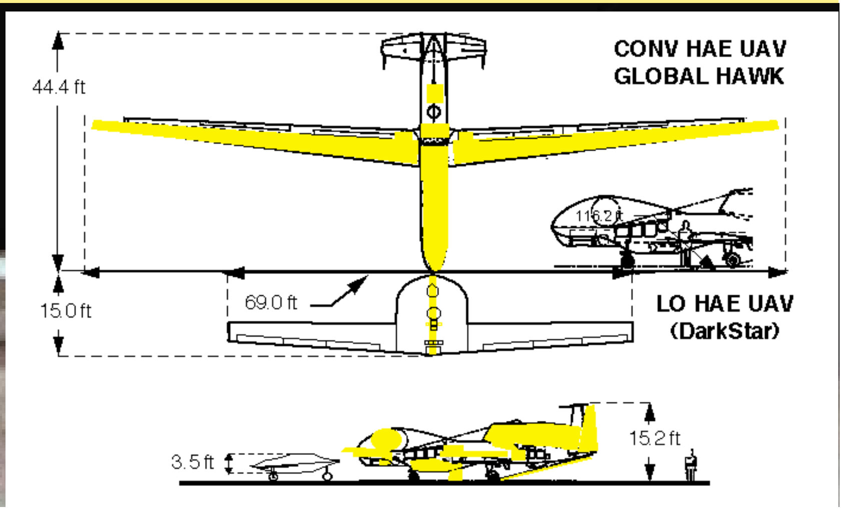
Range 12000 nm, AUW 25,600 lb , range up to 2000nm at 65000ft

flies to an area 1200 miles and remains on station 24 hrs

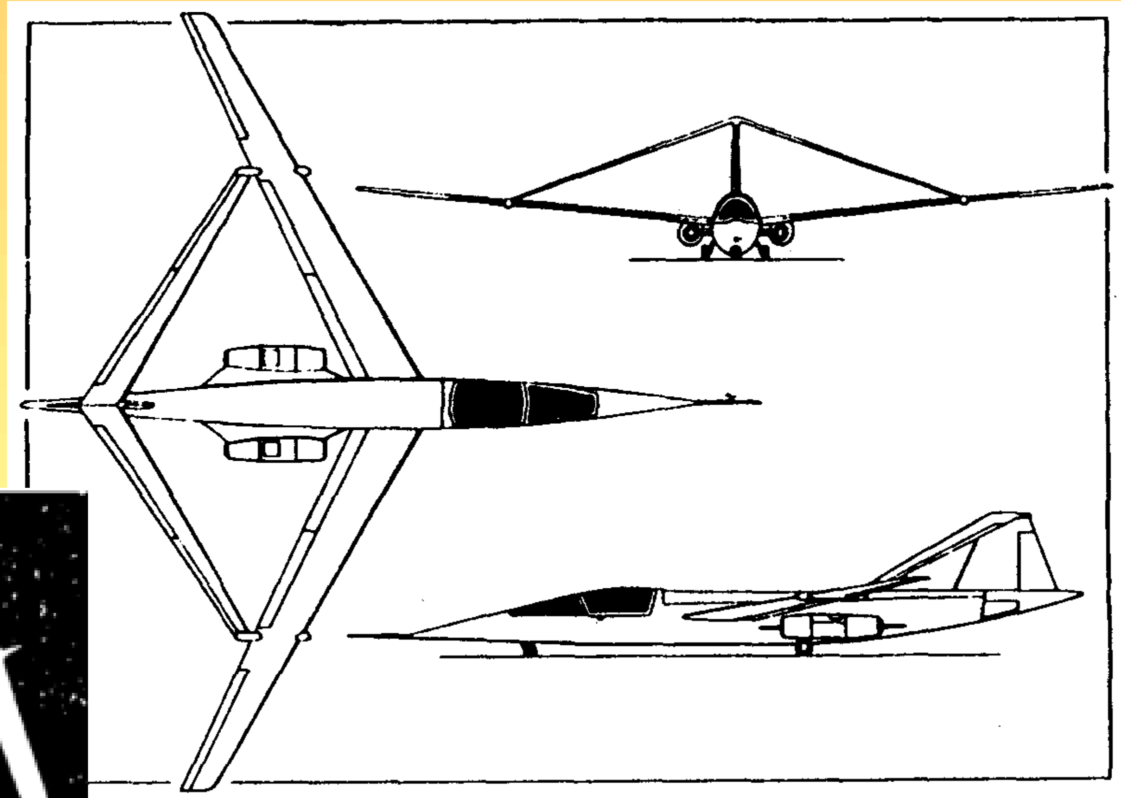
cloud penetrating synthetic aperture radar /
ground moving target indicator, electro-optical and infra-red sensors

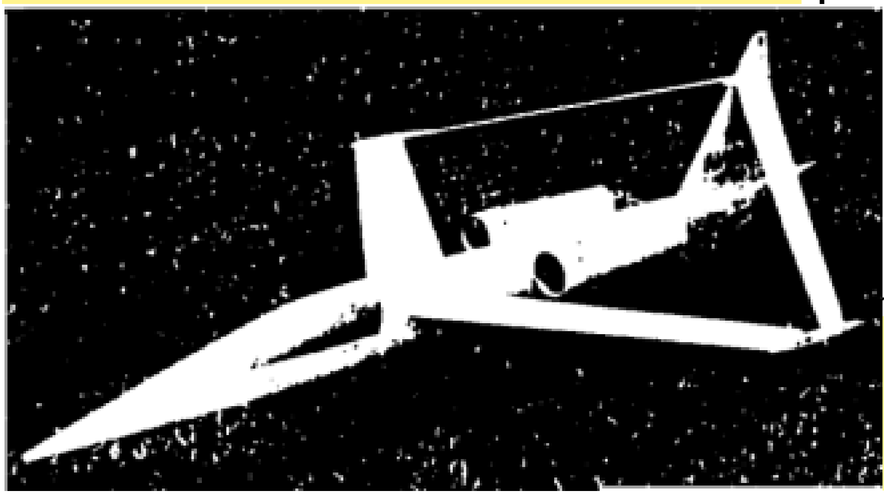
image an area 40,000 square miles (State of Illinois) in 24 hours

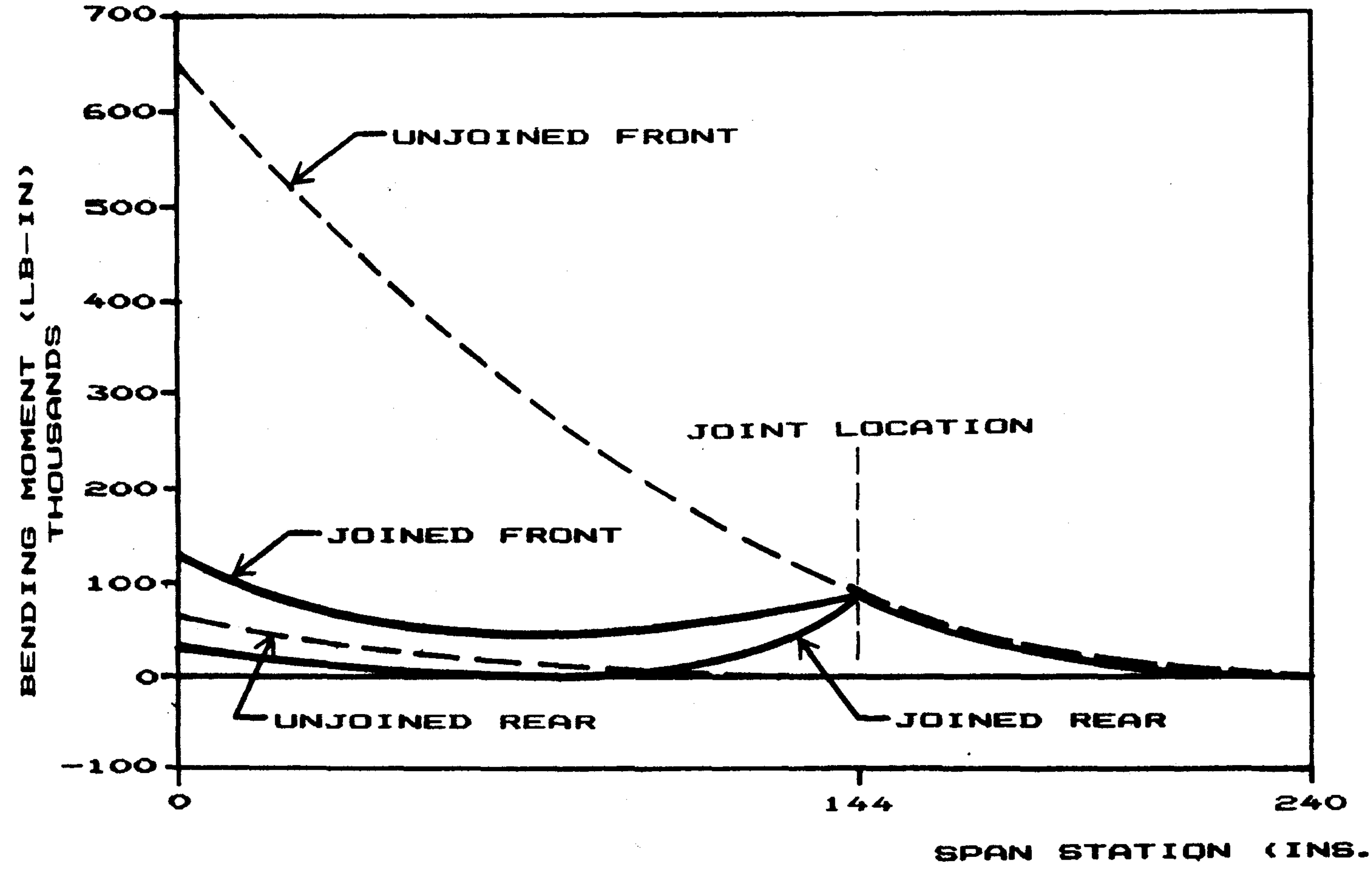




WOLKOVITCH

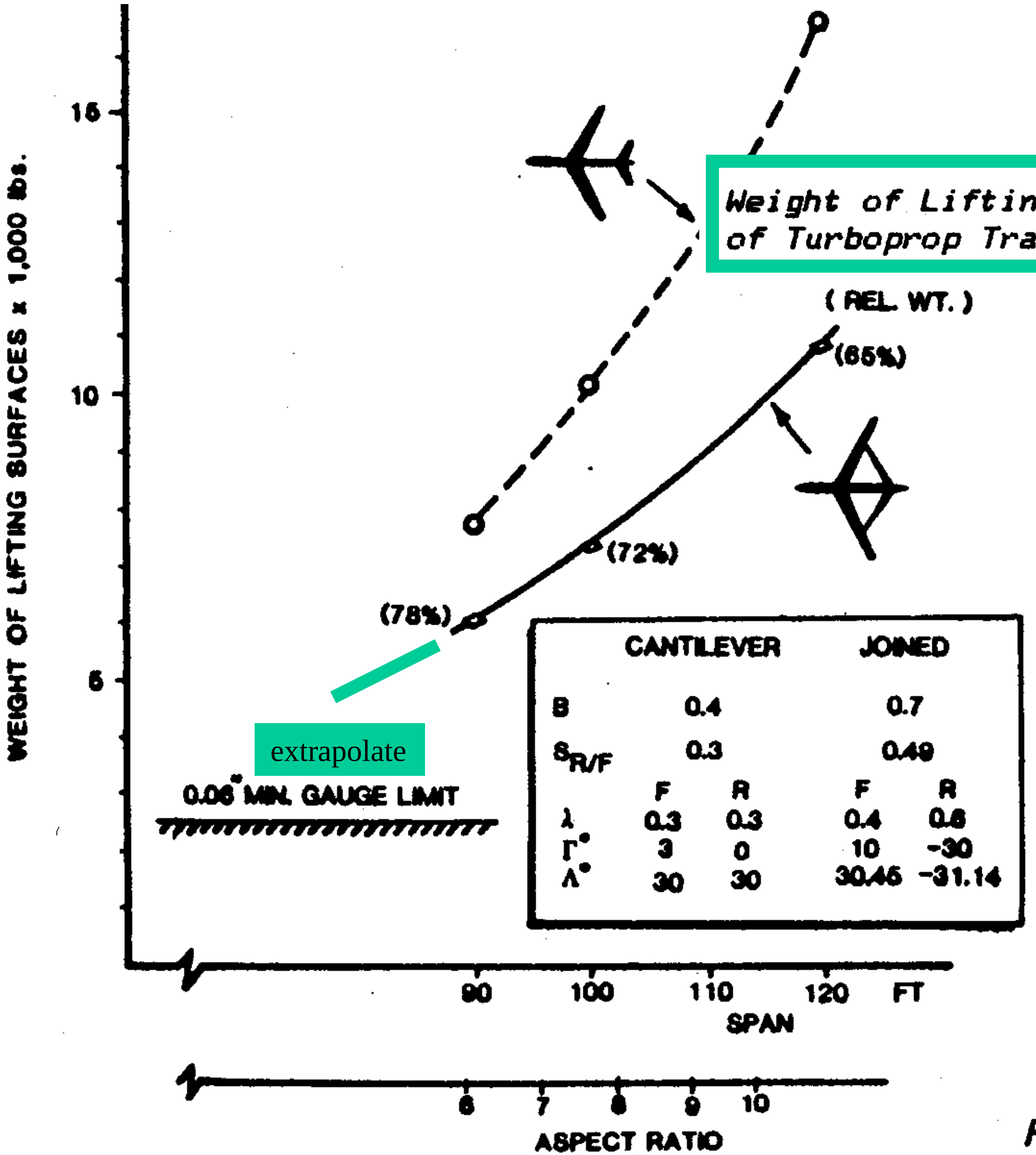




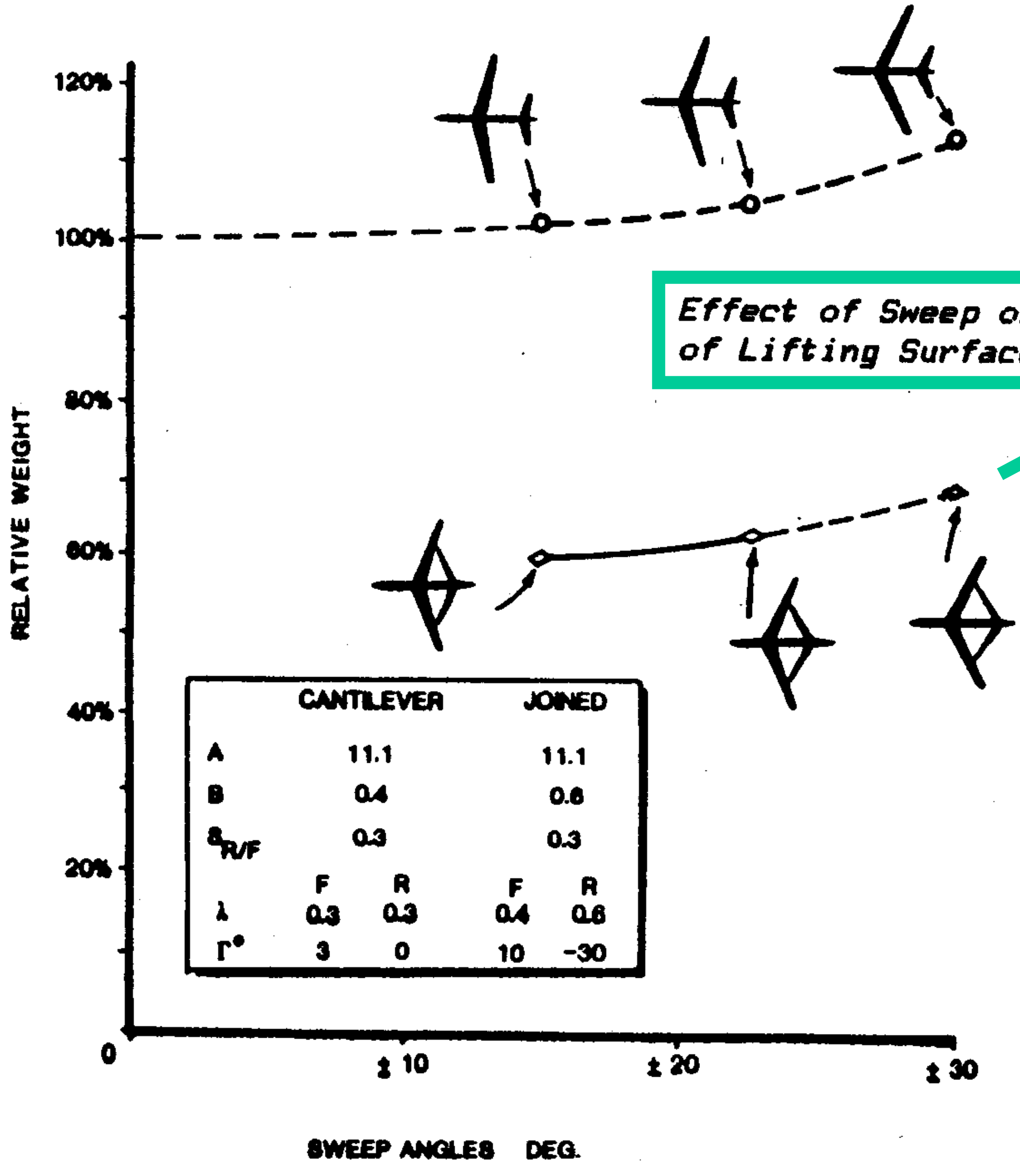


Bending Moments acting on an Inboard-Jointed Joined Wing.

Weight of Lifting Surfaces of Turboprop Transports Versus Aspect Rat

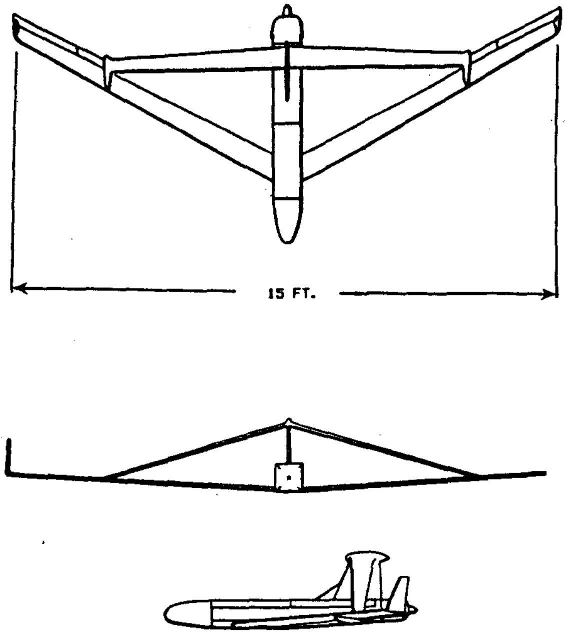


	CANTILEVER		JOINED	
B	0.4		0.7	
$S_{R/F}$	0.3		0.49	
	F	R	F	R
λ	0.3	0.3	0.4	0.6
Γ°	3	0	10	-30
Λ°	30	30	30.45	-31.14



Effect of Sweep on Relative Weight of Lifting Surfaces of Turboprop Transpo

Guess !



11. ACA Industries "LAURA" Long Endurance Remote
Vehicle.

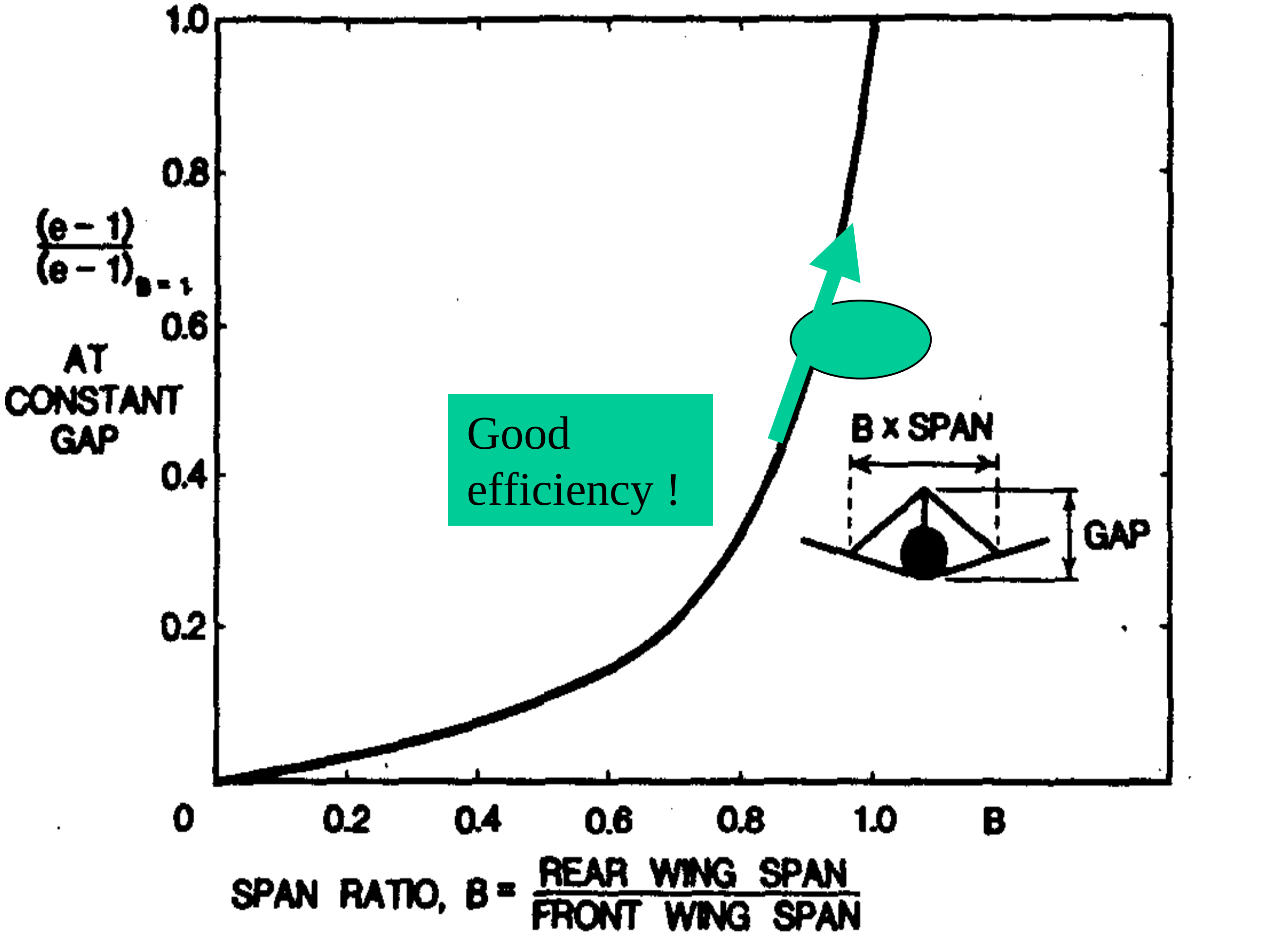
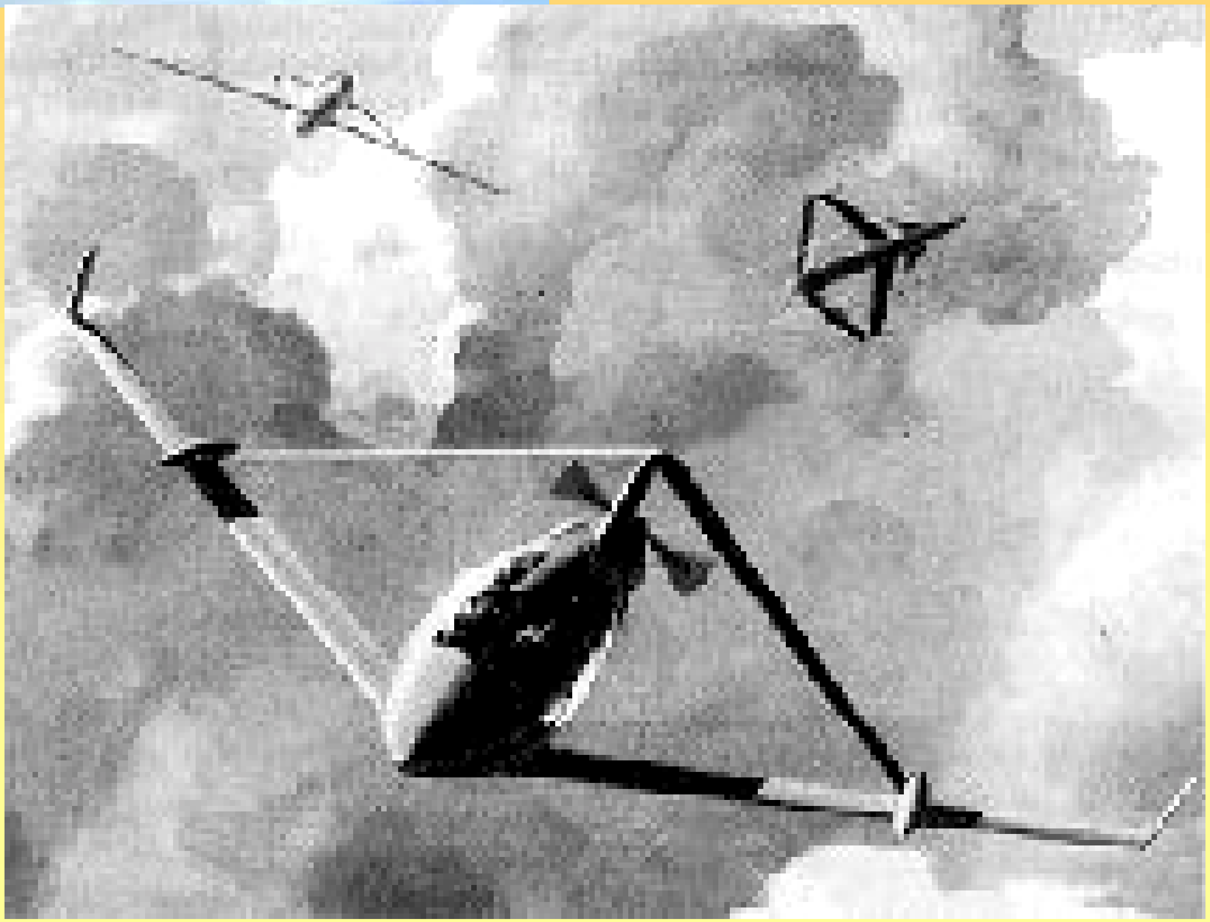
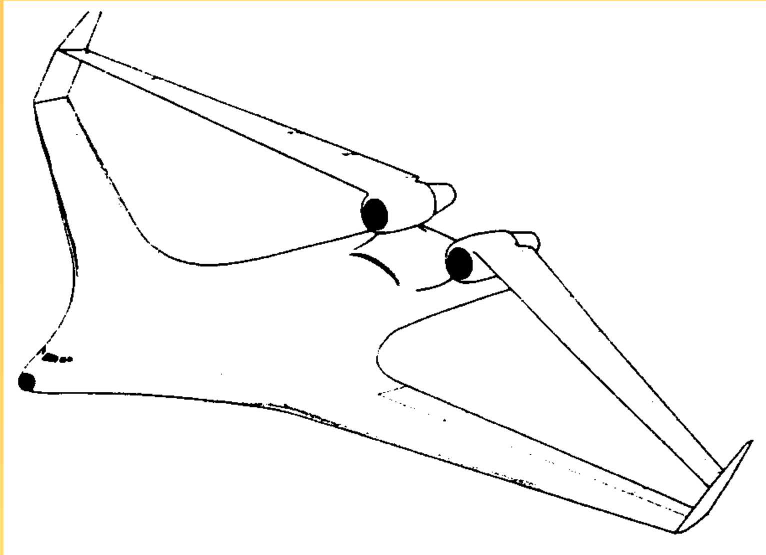


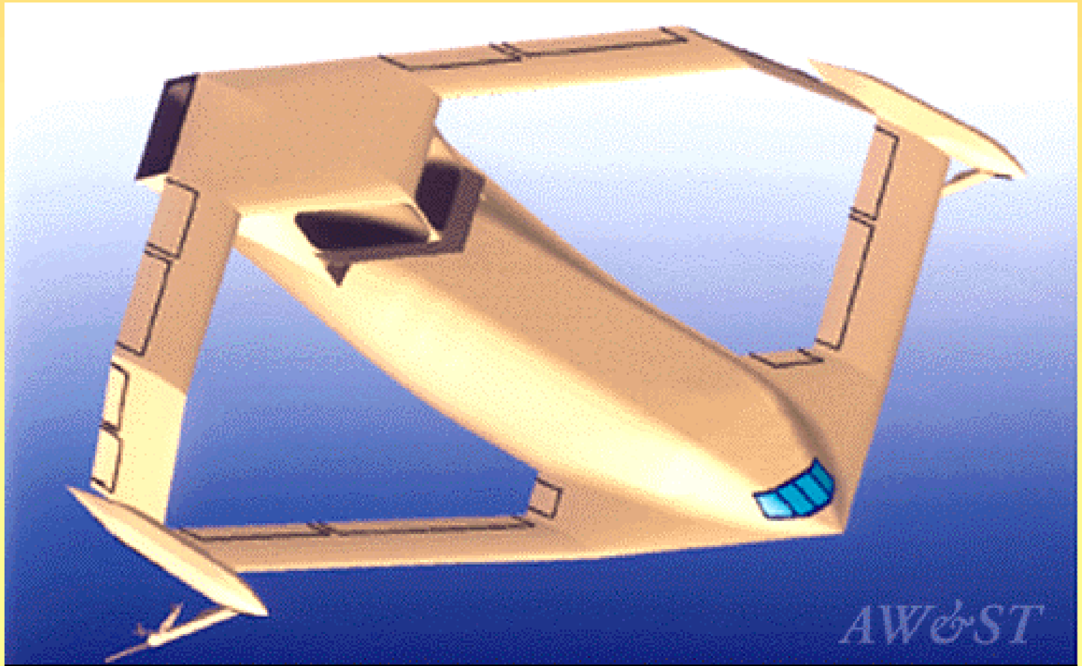
Fig. 12. Effect of Span Ratio on Span-Efficiency Factor.





TANKERS

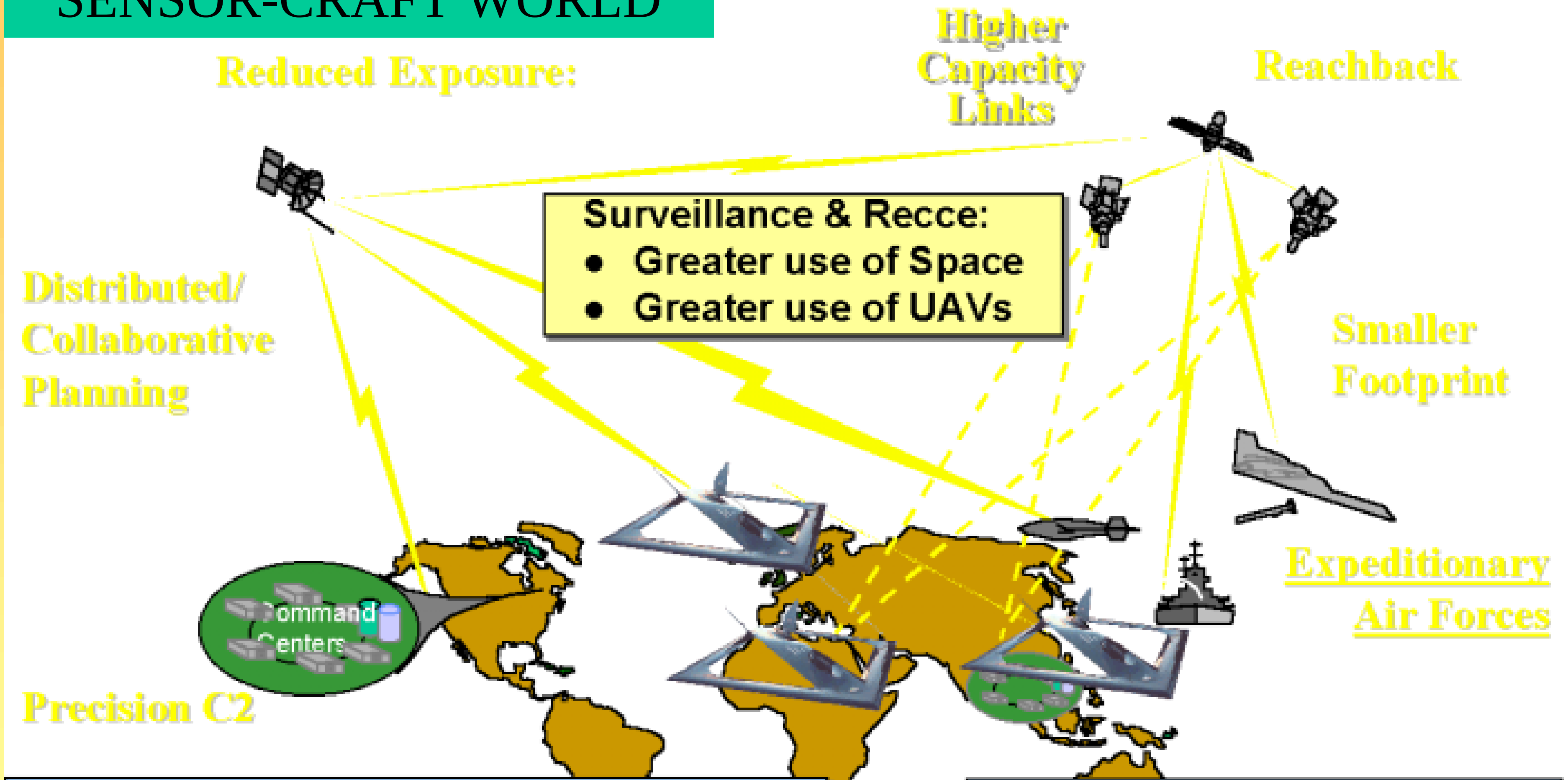
TRANSPORTS



Joined-Wing Transport Concept Features A Refueling Boom On Each Wingtip
And More Control Surfaces Than Conventional Aircraft

AC2ISR: What the Future Will Bring

SENSOR-CRAFT WORLD



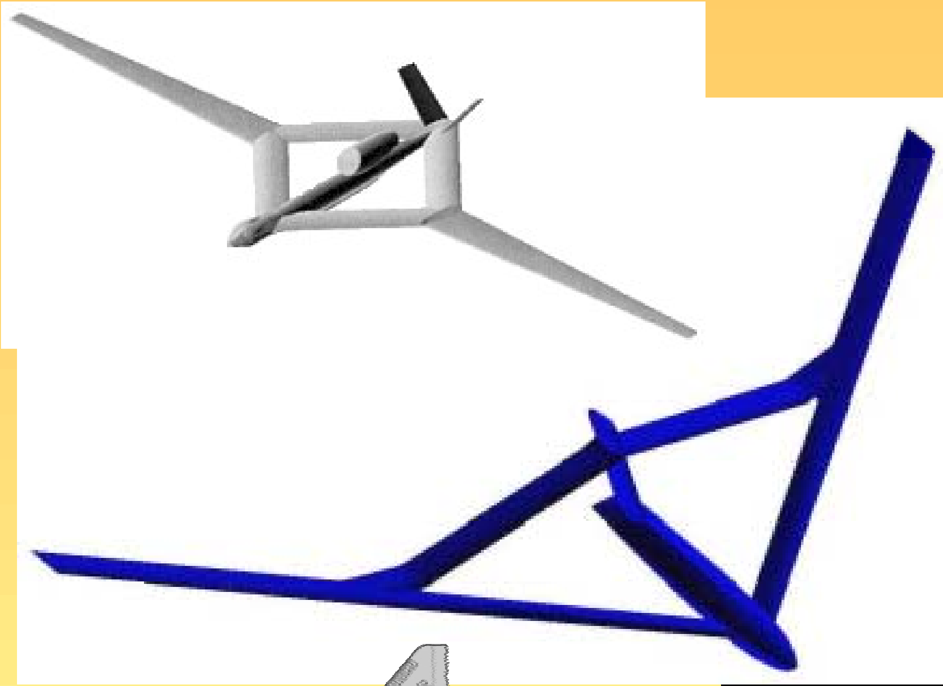
C2:
- Shared Common Operating picture
- Reduced Footprint Command Centers

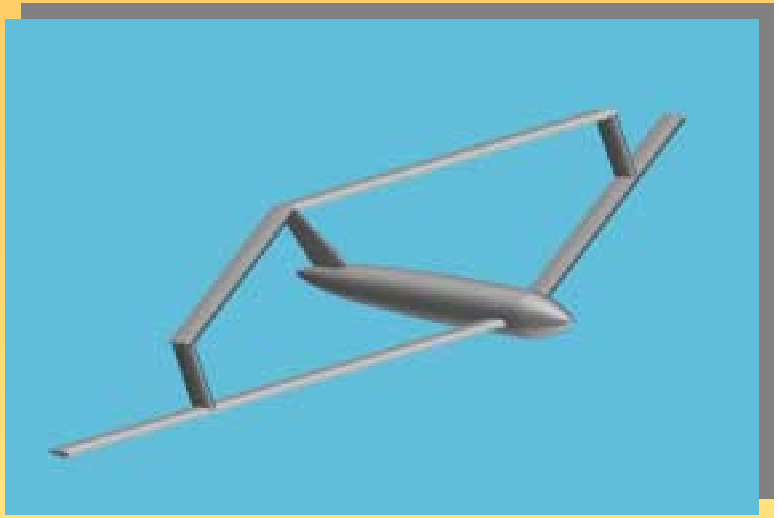
Shooters:
- Improved Stand-off-PGMs
- New UCAV Platforms

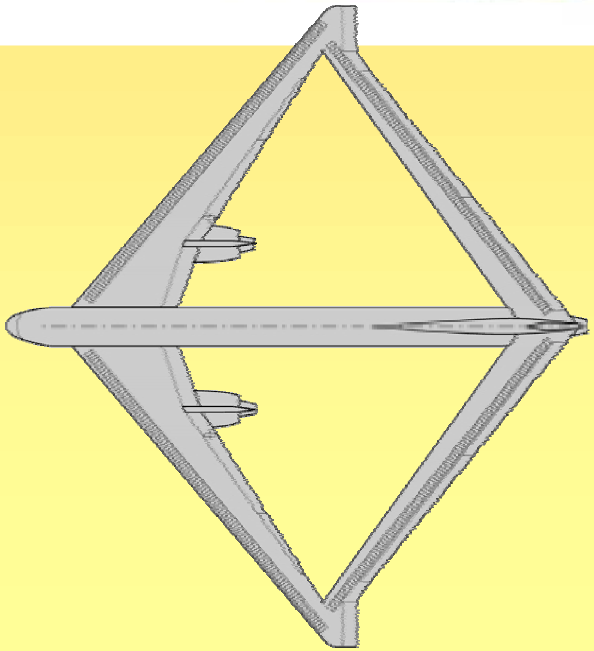
Right Info to the Right Warfighter at the Right Time for the Right Decision

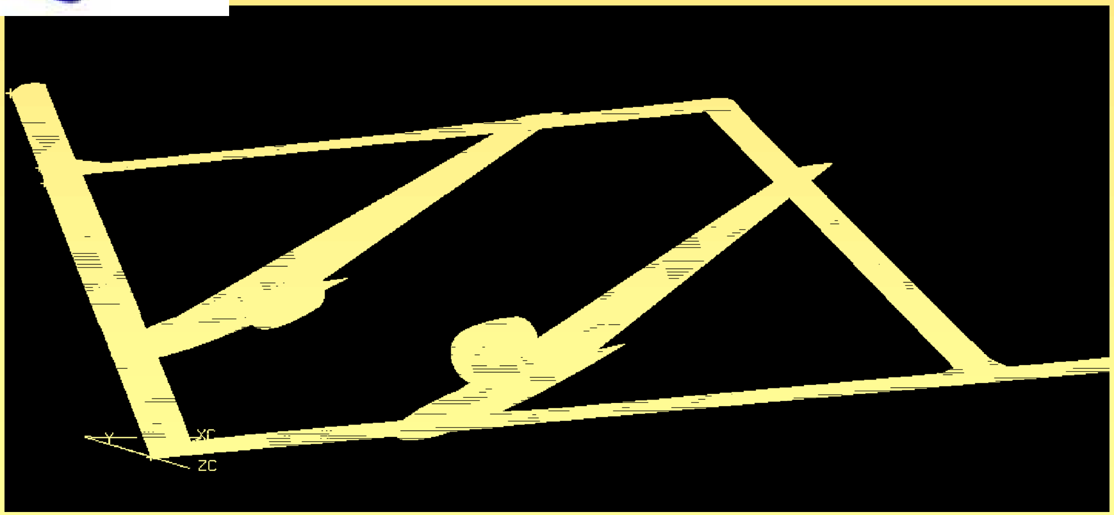
Sensor Craft UAV as Element of Global Awareness/Global Engagement Vision

Other joined-wing possibilities

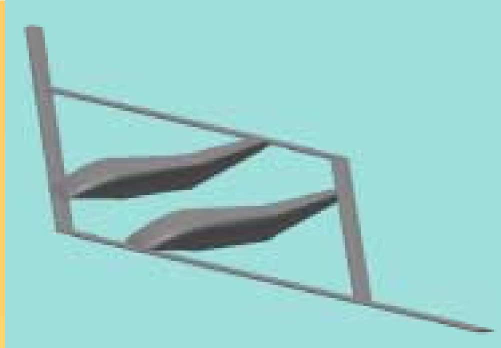


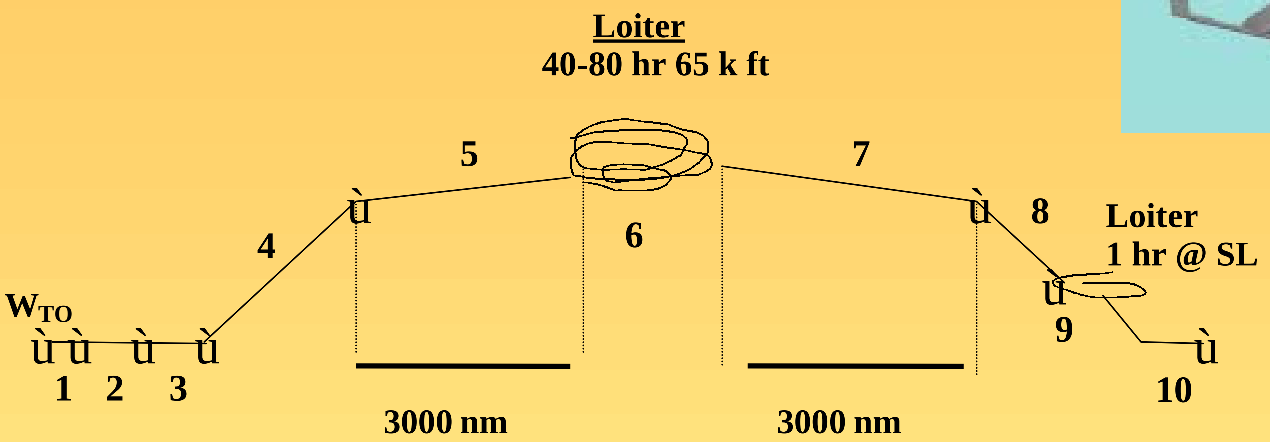






Mission profile and requirements





Mission Segments

1. Engine Start & Warm-up
2. Taxi
3. Takeoff
4. Climb & Accelerate to Cruise
5. Cruise out 3000
6. Loiter
7. Return Cruise
8. Descend
9. Loiter at Sea Level
10. Landing, Taxi, Shutdown

Cruise Radius: 3000 nm

Loiter: 65 Kft for 40 - 80 hr (at 3000 nm range)

Payload: 4000 lb Field Length: 5350 ft over 50 ft Obstacle (SLS)

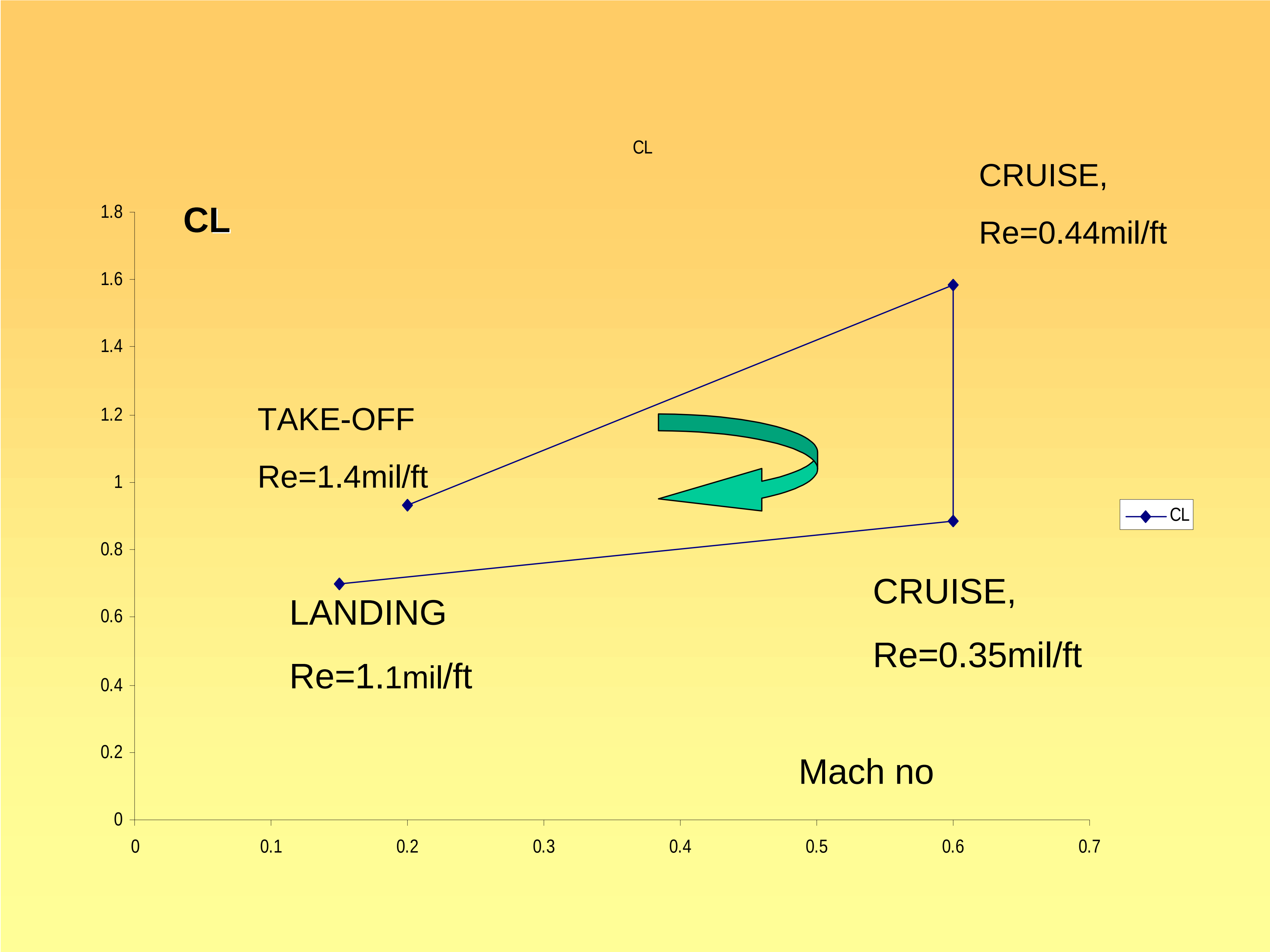
Control: 20 kt cross-wind on takeoff and landing

Flight duration 4-6 days
Implies a Wide Flight Envelope

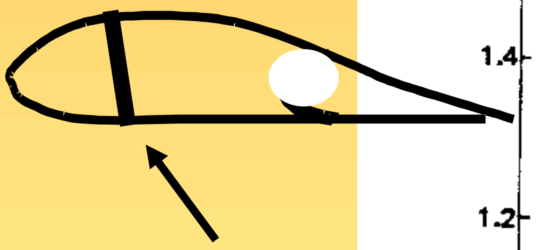
W/S range of interest: 30 - 60

T/W range of interest: .30 -.50

Altitude - ft
ht
CRUISE
Mach 0.6,
CL=0.88
Re=0.35mil/ft
Mach 0.6,
CL=1.59
Re=0.4 mil/ft
Mach 0.15
CL=0.7
Re=1.1mil/ft
LAND
TAKE-OFF
Mach 0.2
CL=0.95
Re=1.4mil/ft
ht
0
10000
20000
30000
40000
50000
60000
70000
80000
Weight - lb

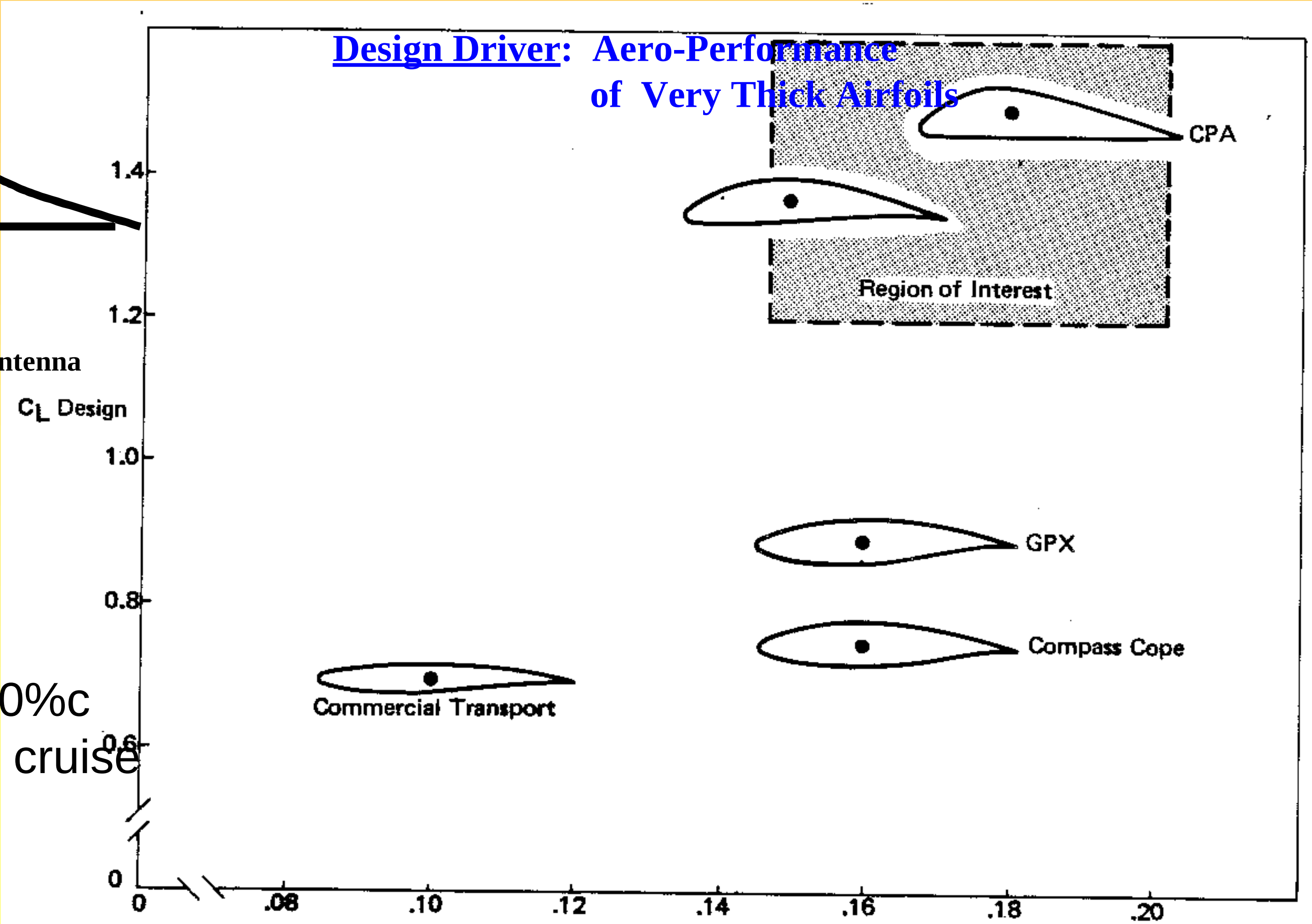

CL
CRUISE,
Re=0.44mil/ft
CL
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
TAKE-OFF
Re=1.4mil/ft
LANDING
Re=1.1mil/ft
CRUISE,
Re=0.35mil/ft
Mach no
CL
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7

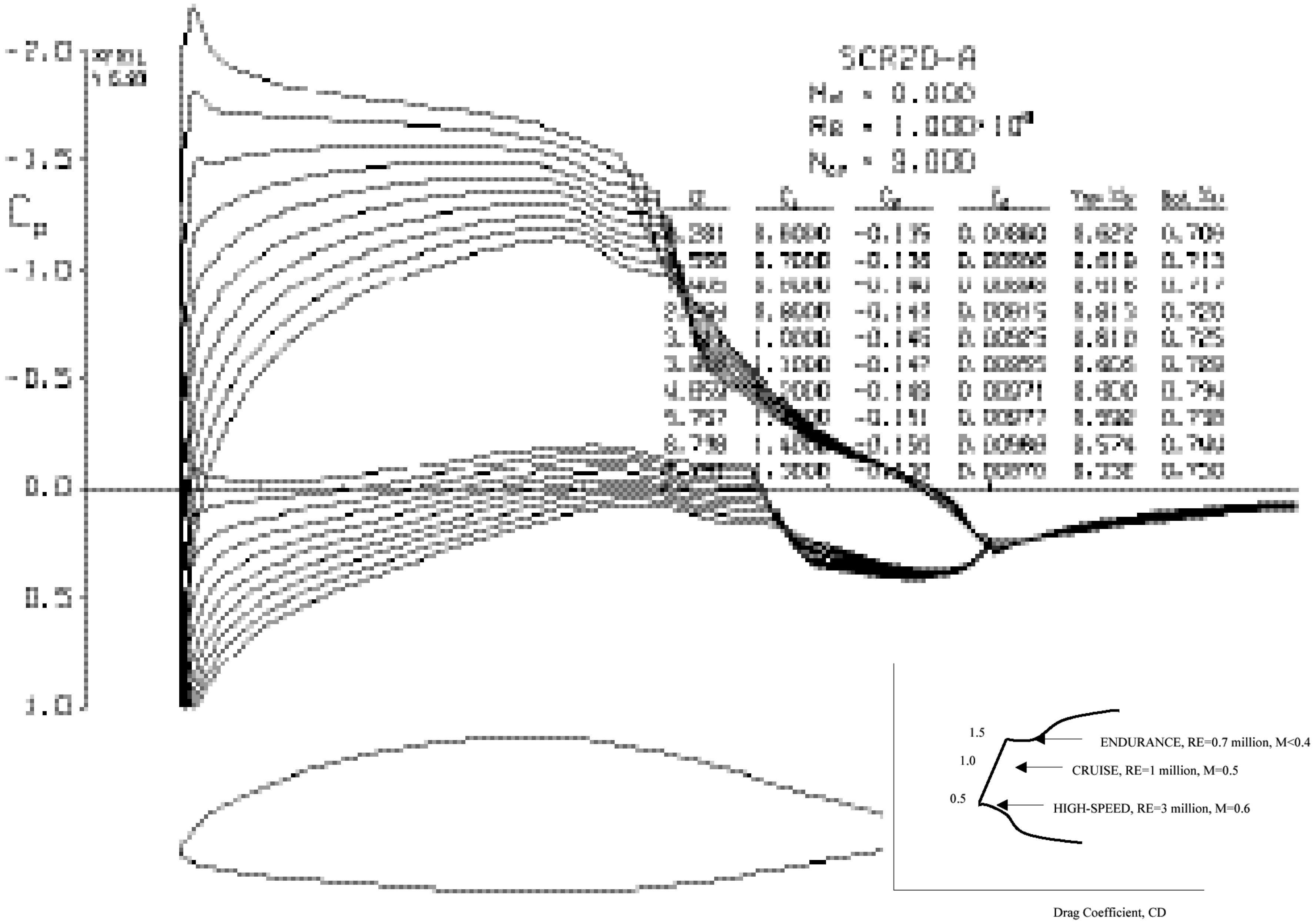
Reference Configuration - Antenna Integration



2-D Driver
High t/c
High L/D
Laminar Flow 50%c
Critical Mach at cruise
Low Re

<u>Design Driver</u>: Aero-Performance of Very Thick Airfoils

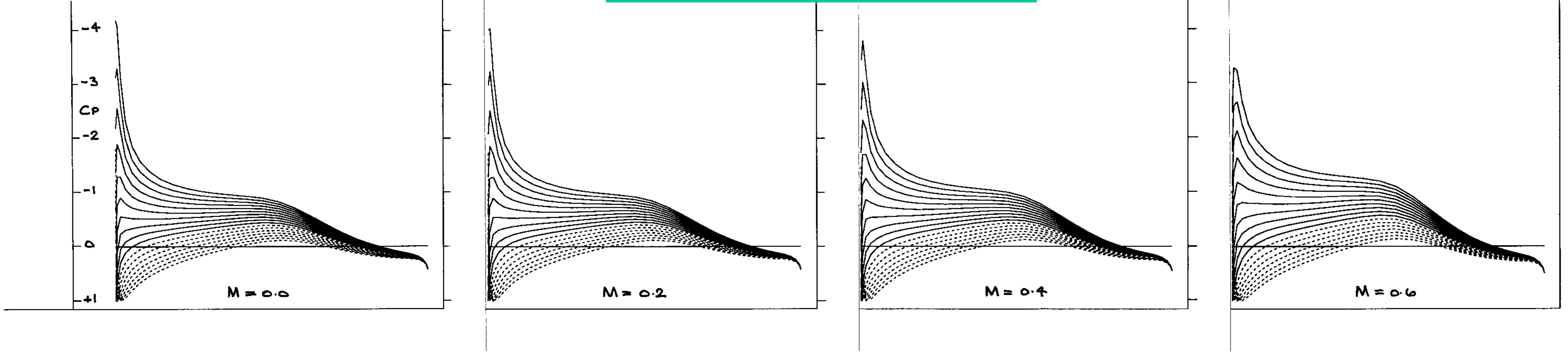




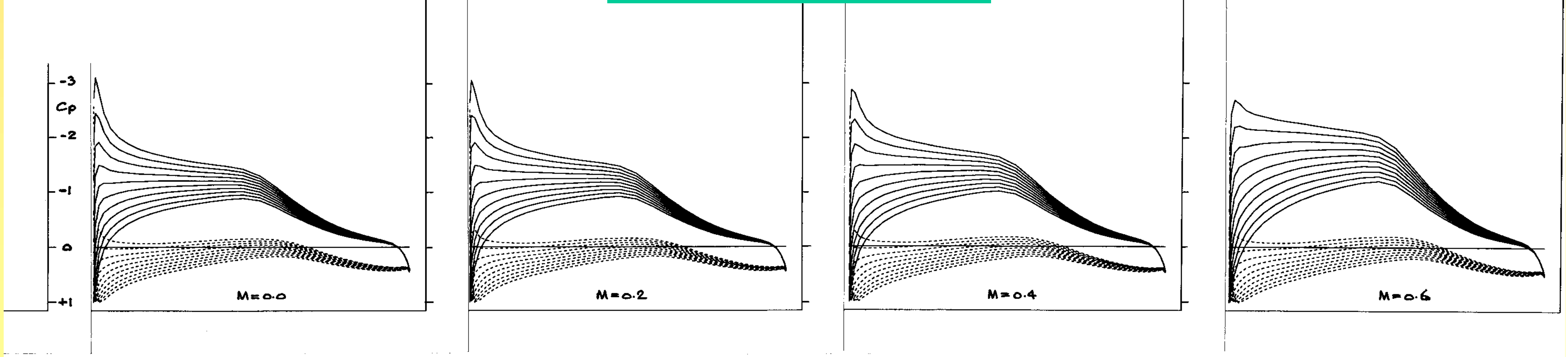
19.6% t/c, Navier-Stokes Results at Re 1 million, Mach 0.01, Biber & Tilmann

2-D CALCULATIONS, INVISCID, MACH no VARIES from 0.0 to 0.6

t/c 16% uncambered

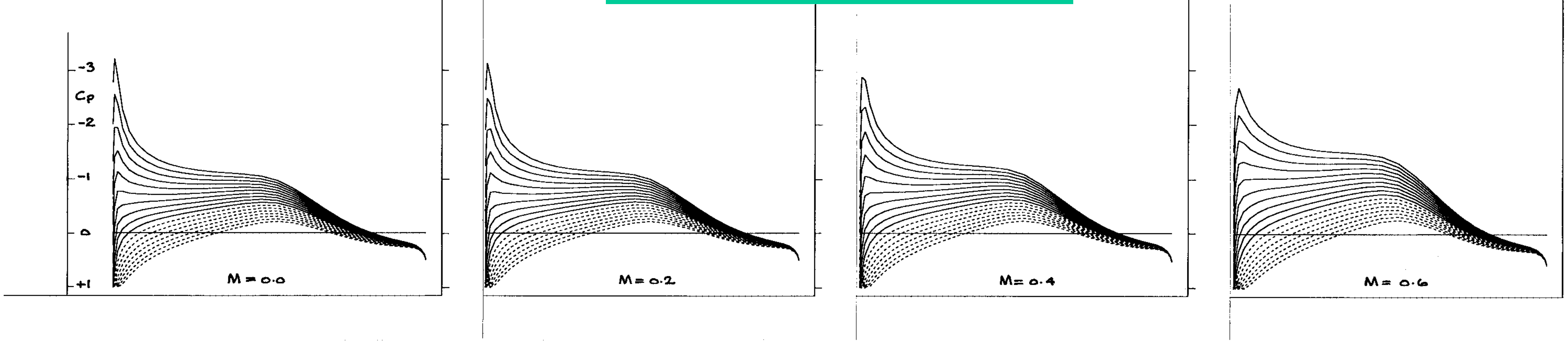


t/c 16% cambered

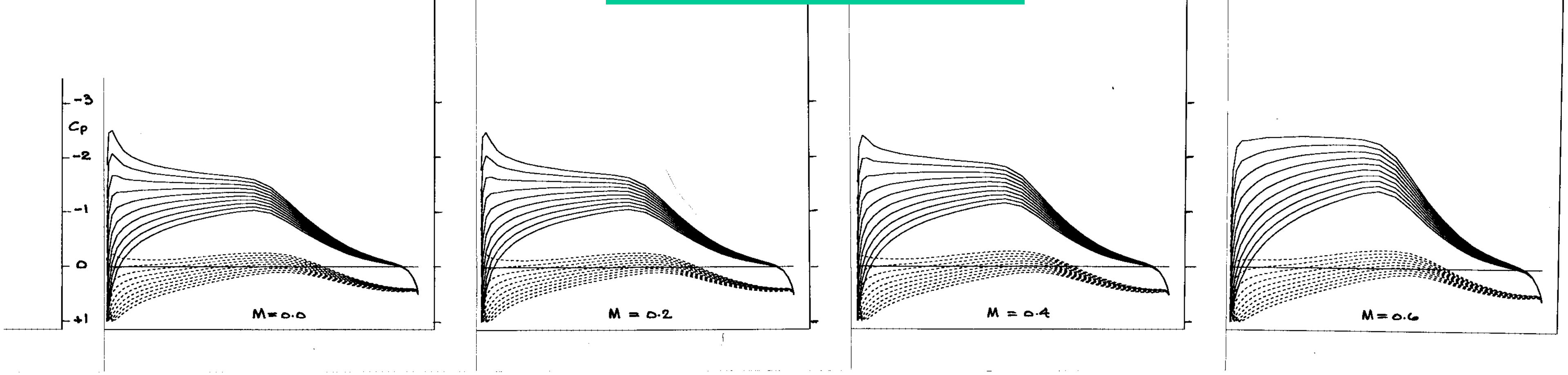


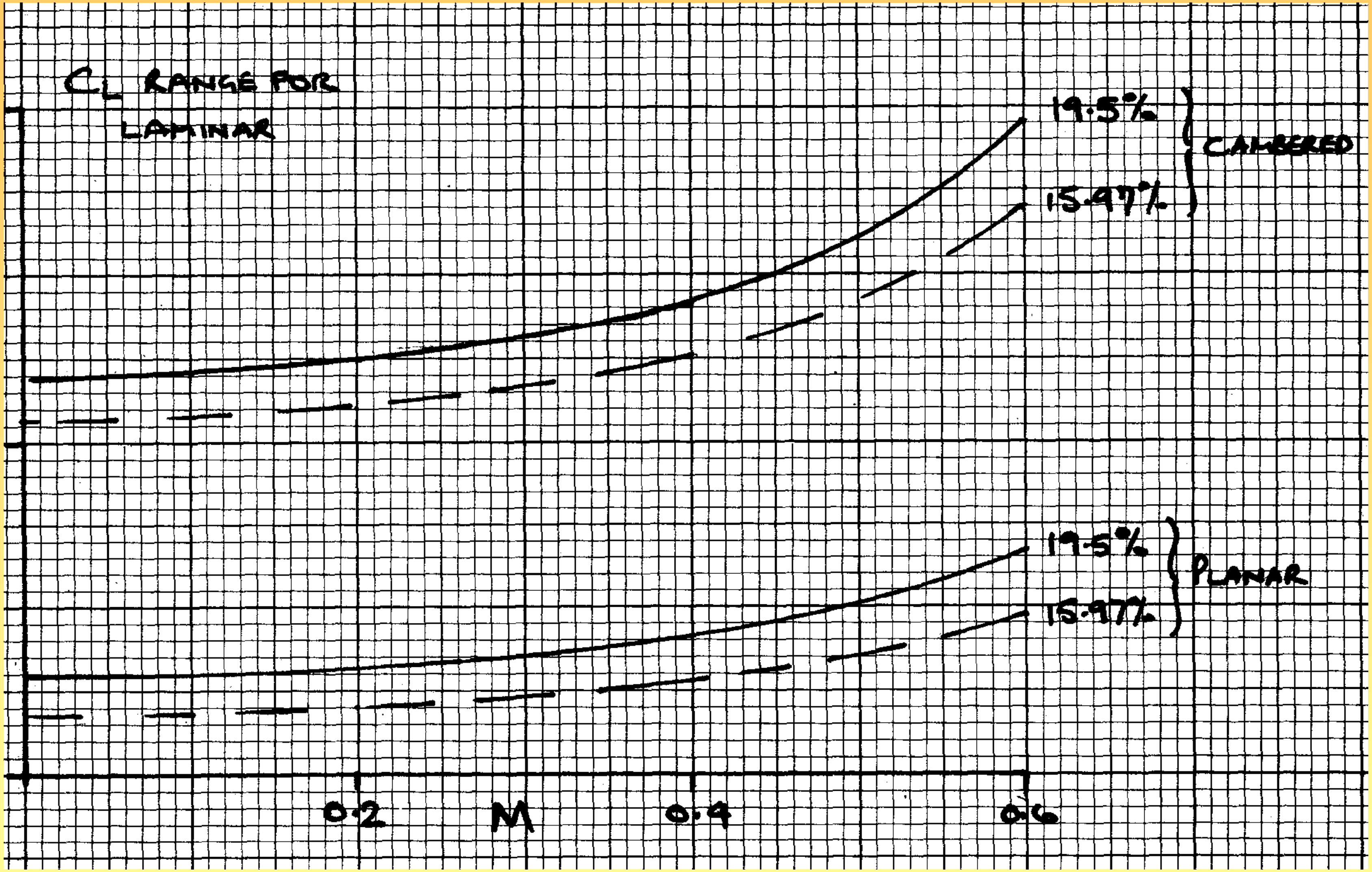
2-D CALCULATIONS, INVISCID, MACH no VARIES from 0.0 to 0.6

t/c 19.6% uncambered



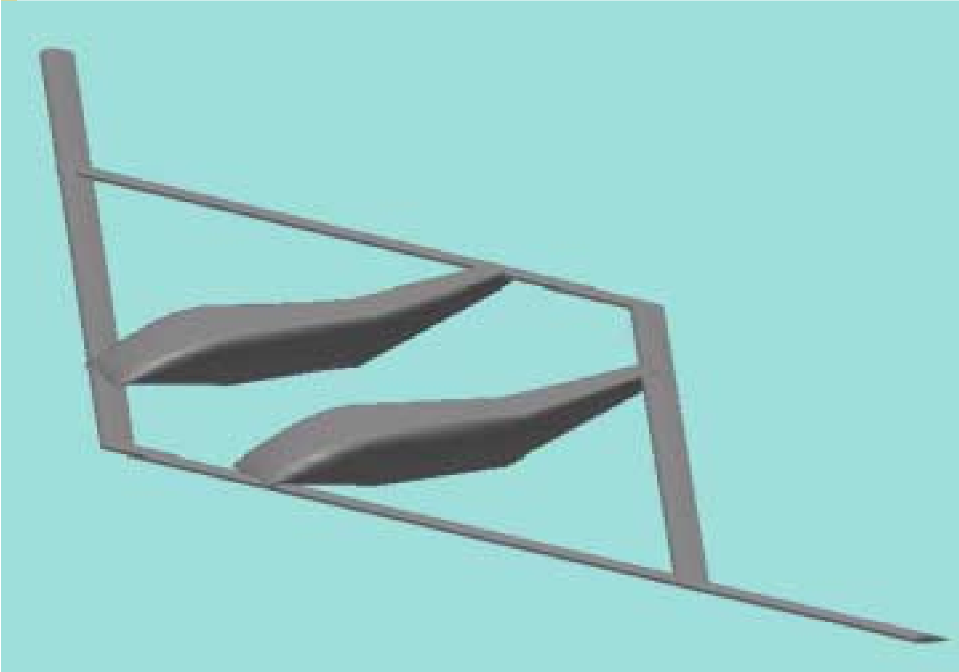
t/c 19.6% cambered



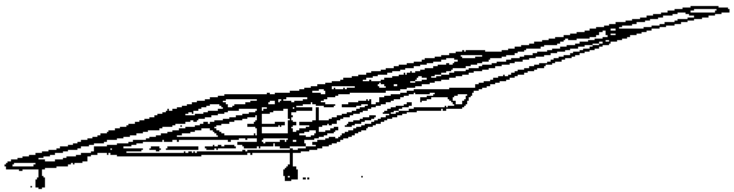


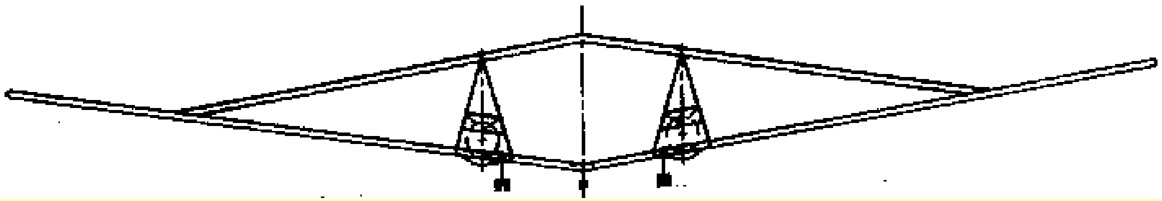
SUMMARISING THE AEROFOIL PERFORMANCE,
LAMINAR FLOW CAPABILITY Uncambered & Cambered

Reference Configuration



ft

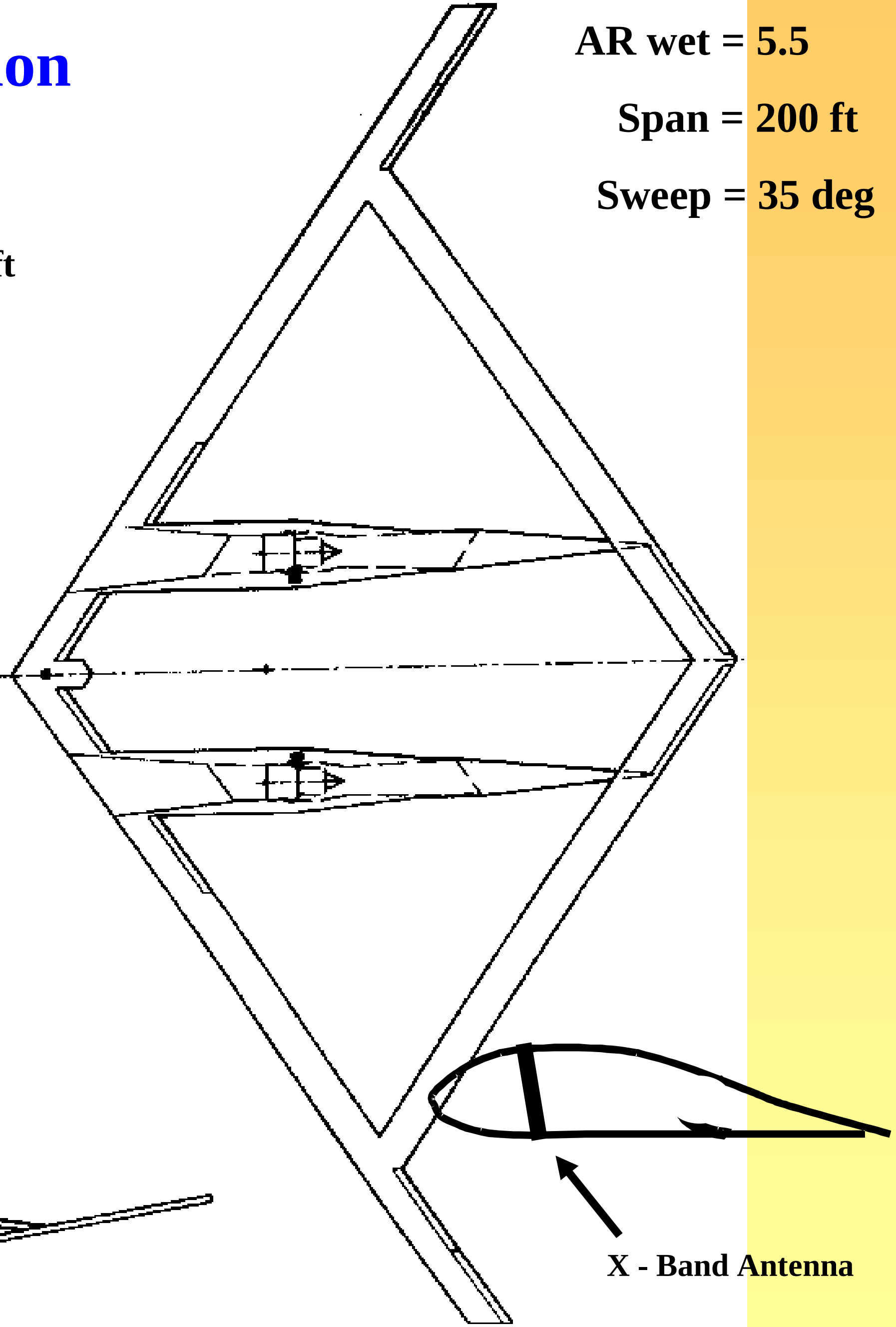


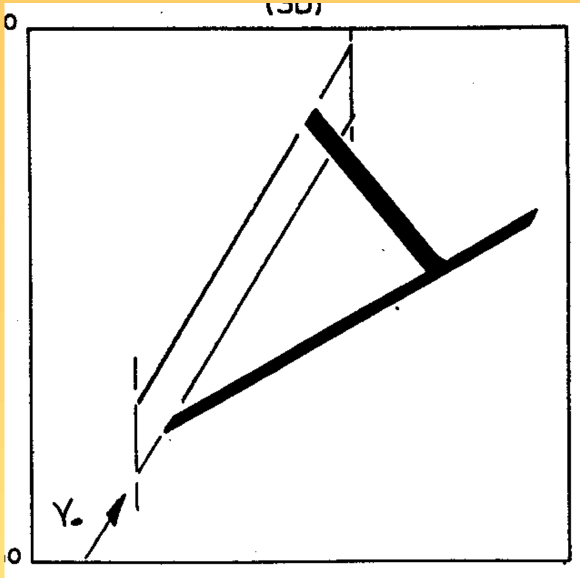


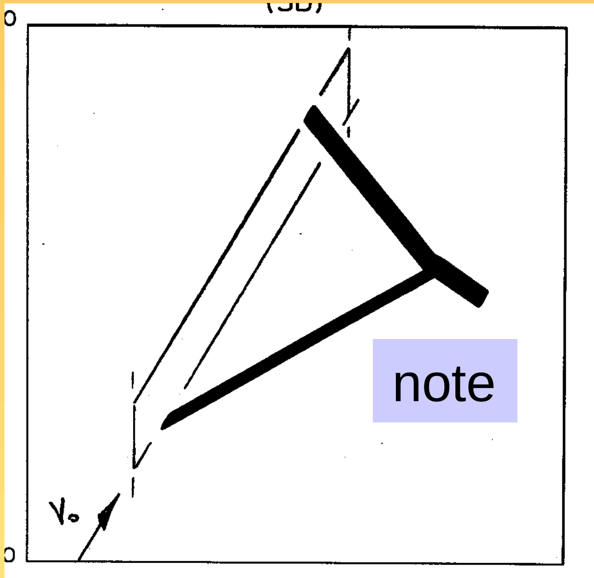
AR wet = 5.5

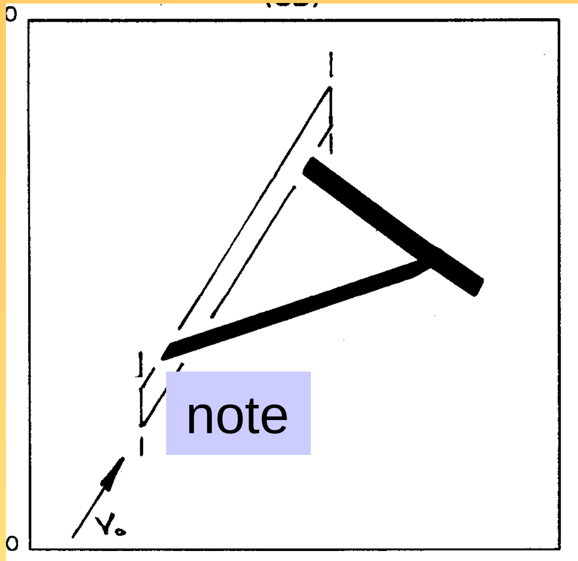
Span = 200 ft

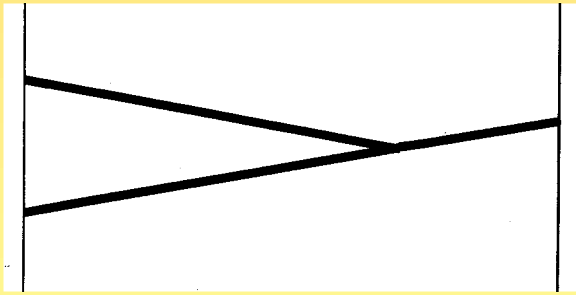
Sweep = 35 deg











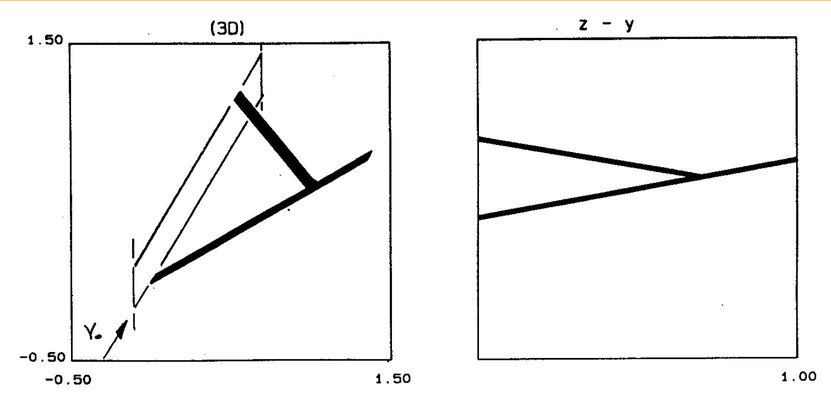
Identical frontal view

AT1

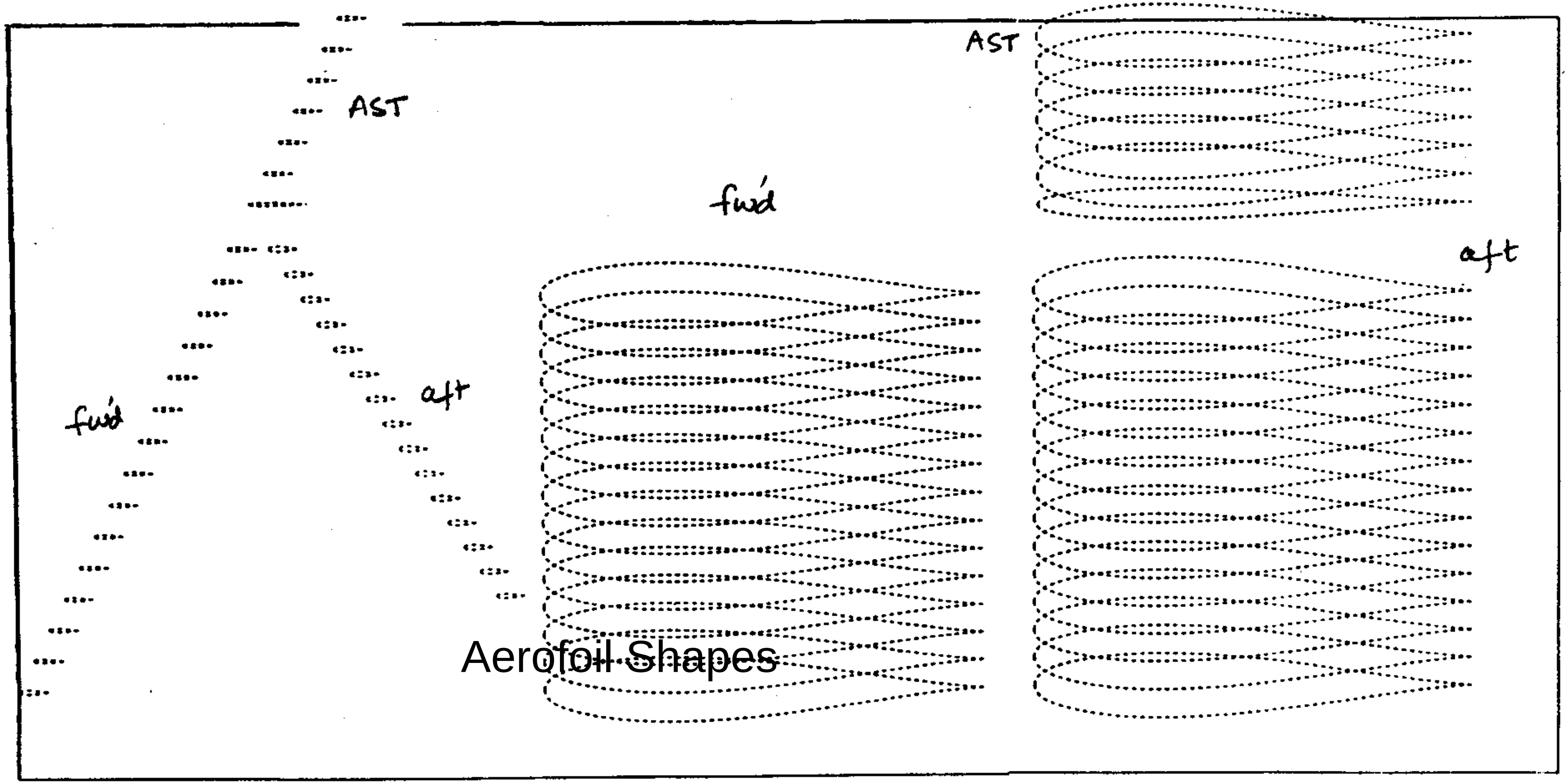
FT1

FT2

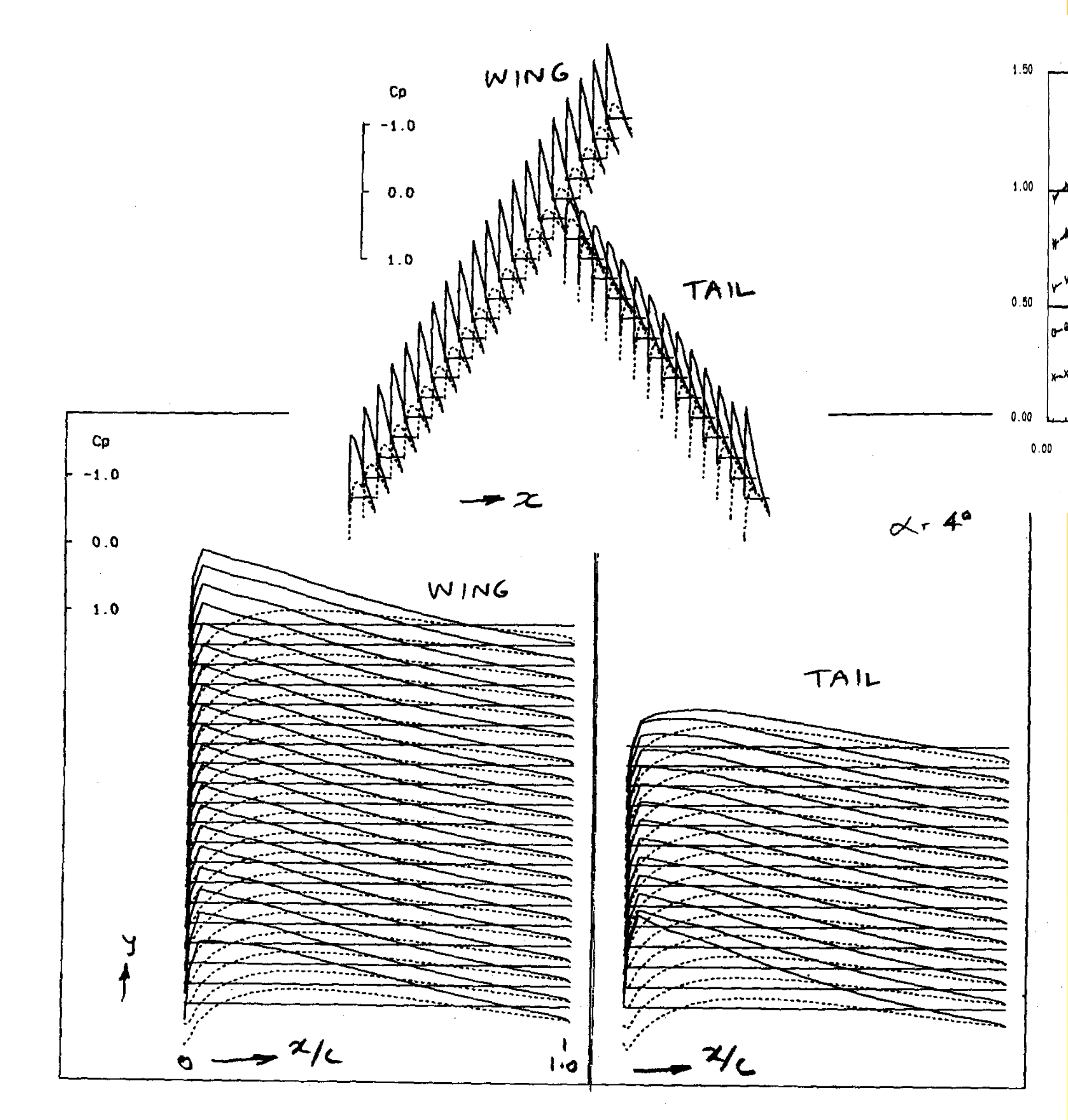
JOINED WING CONFIGURATIONS

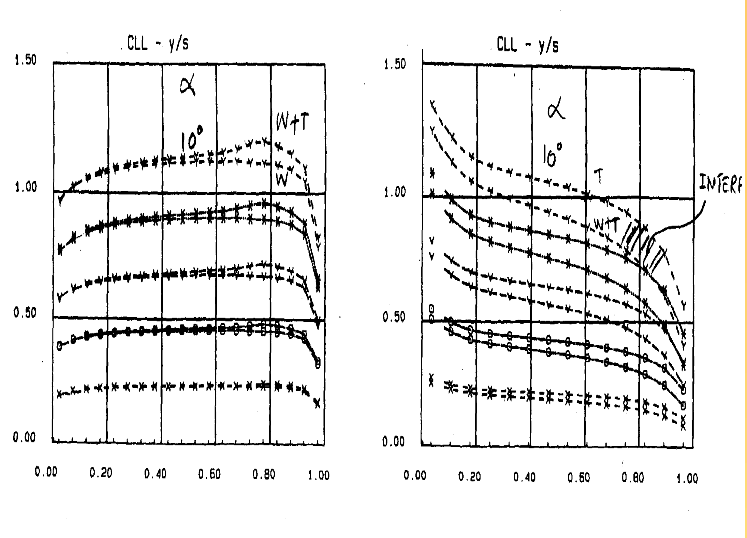


AT! CONFIGURATION



Aerofoil Shapes



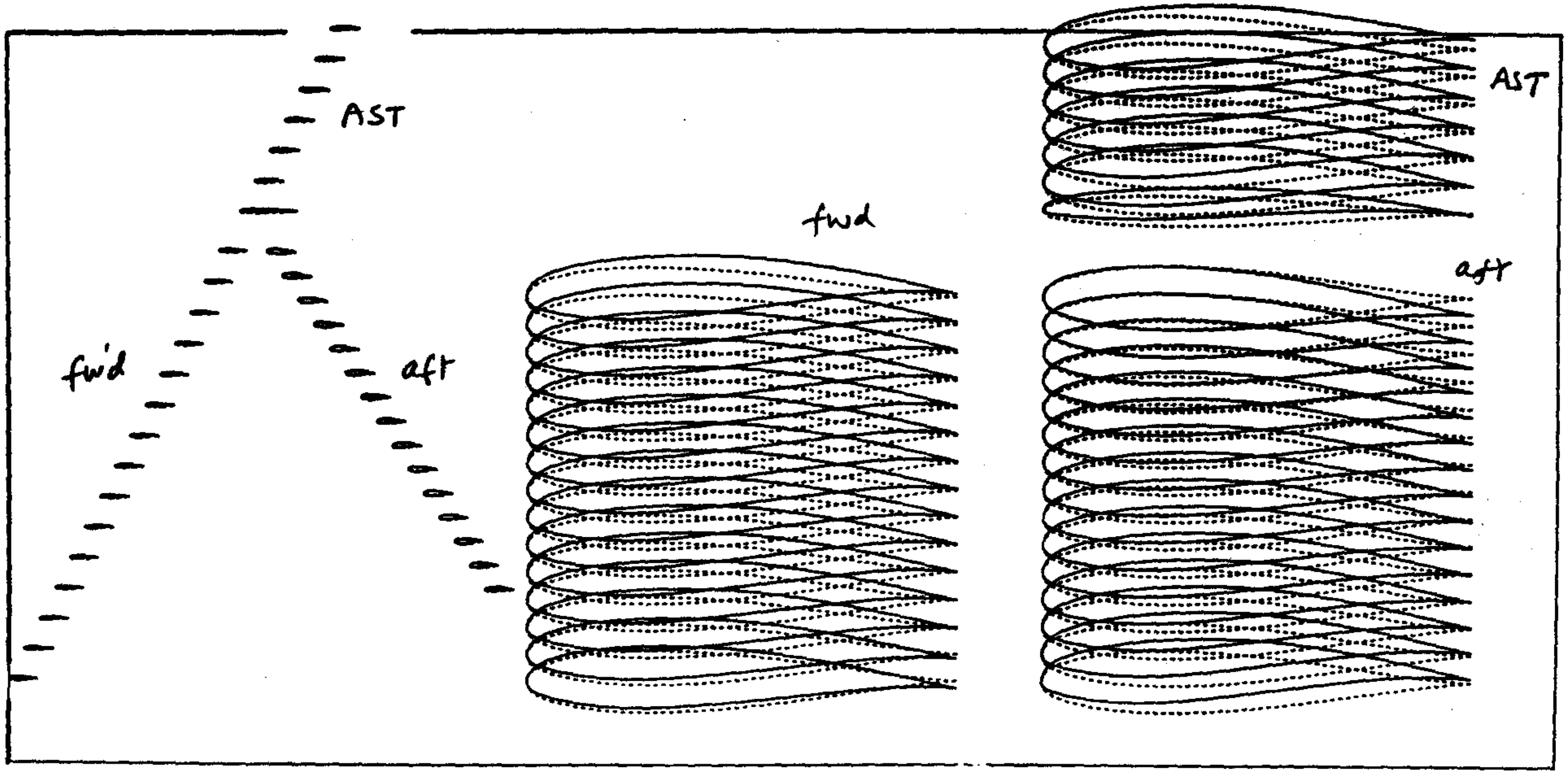


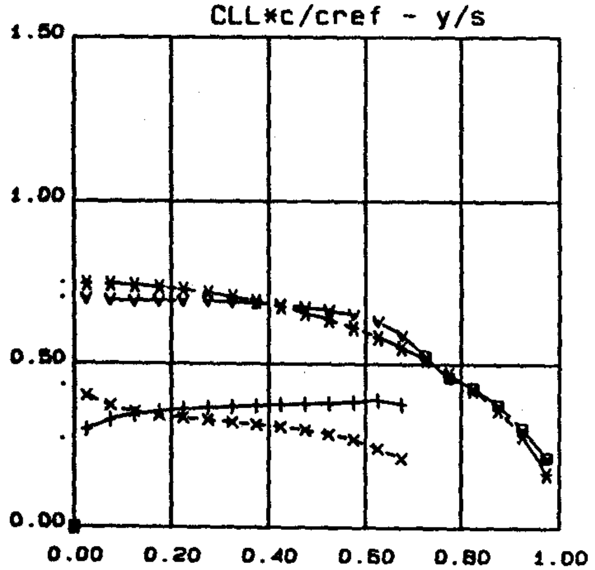
AT!, BASIC CHARACTERISTICS, Uncambered Aerofoils
Cp Distributions & Interference Effects On Spanwise Loadings

DESIGNED WING,Super-Critical Type Aerofoil, Twist & camber

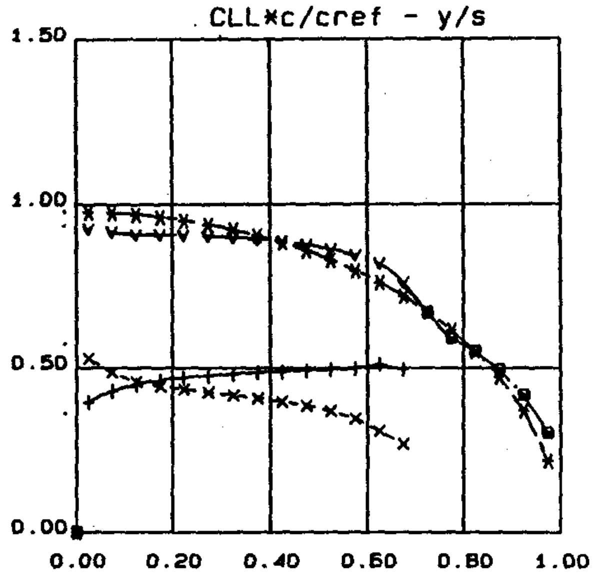
Assume Zero Static Margin (Neutral Stability)

Respective Wing Settings Follow, Use Panel Method

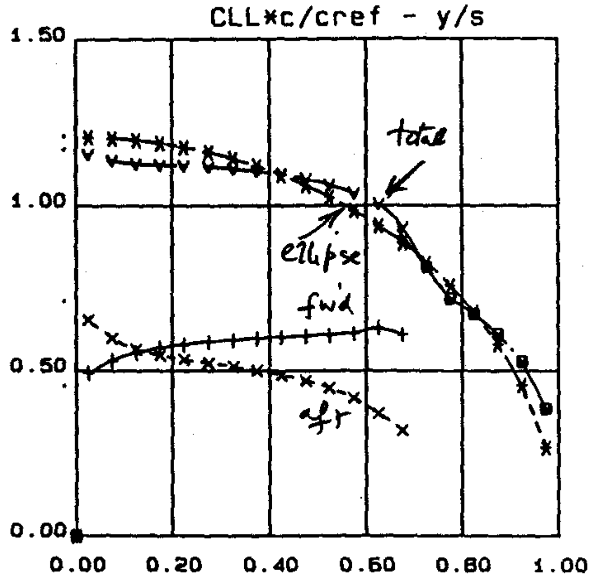




(α, C_L) = (3.25°, 0.588)

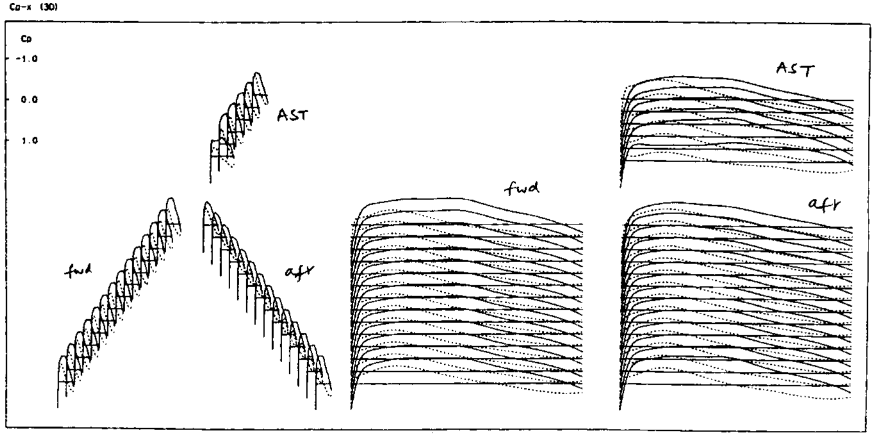


(α, C_L) = (4.25°, 0.768),

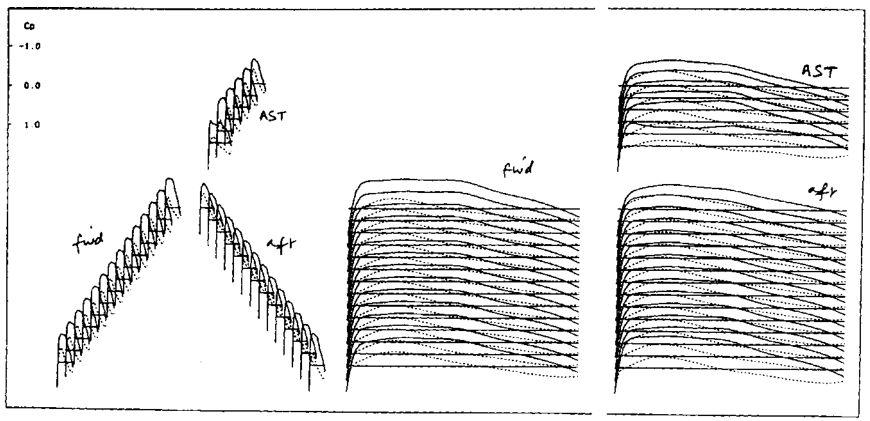


(α, C_L) = (5.25°, 0.946)

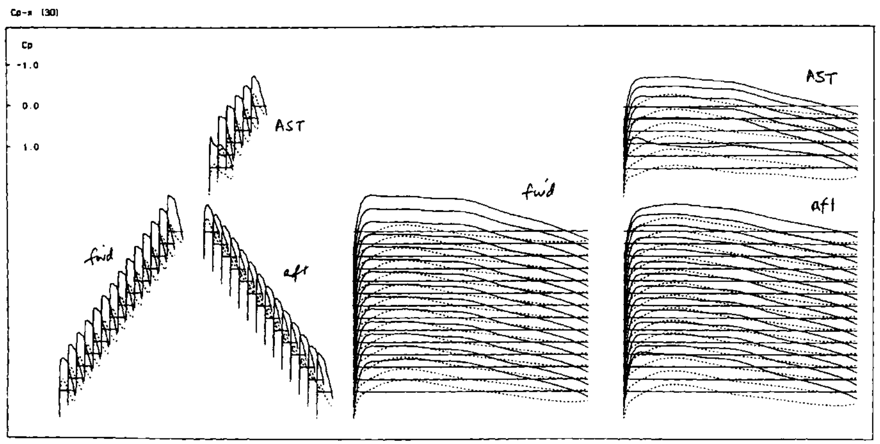
Spanwise Loadings AoA = 3.25, 4.25, 5.25



(a) (α, C_L) = (3.25°, 0.588)



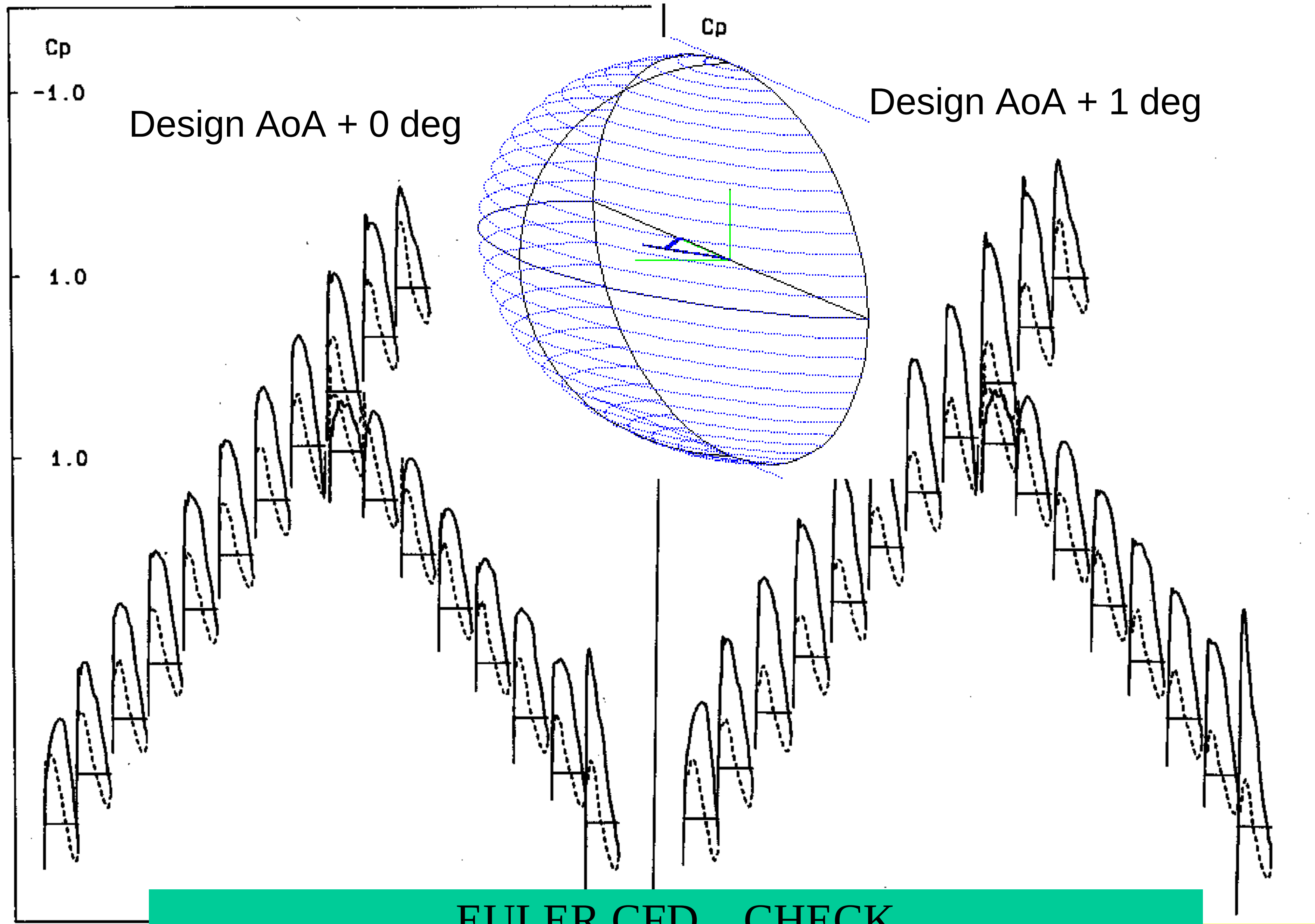
(b) (α, C_L) = (4.25°, 0.768)



(c) (α, C_L) = (5.25°, 0.946)

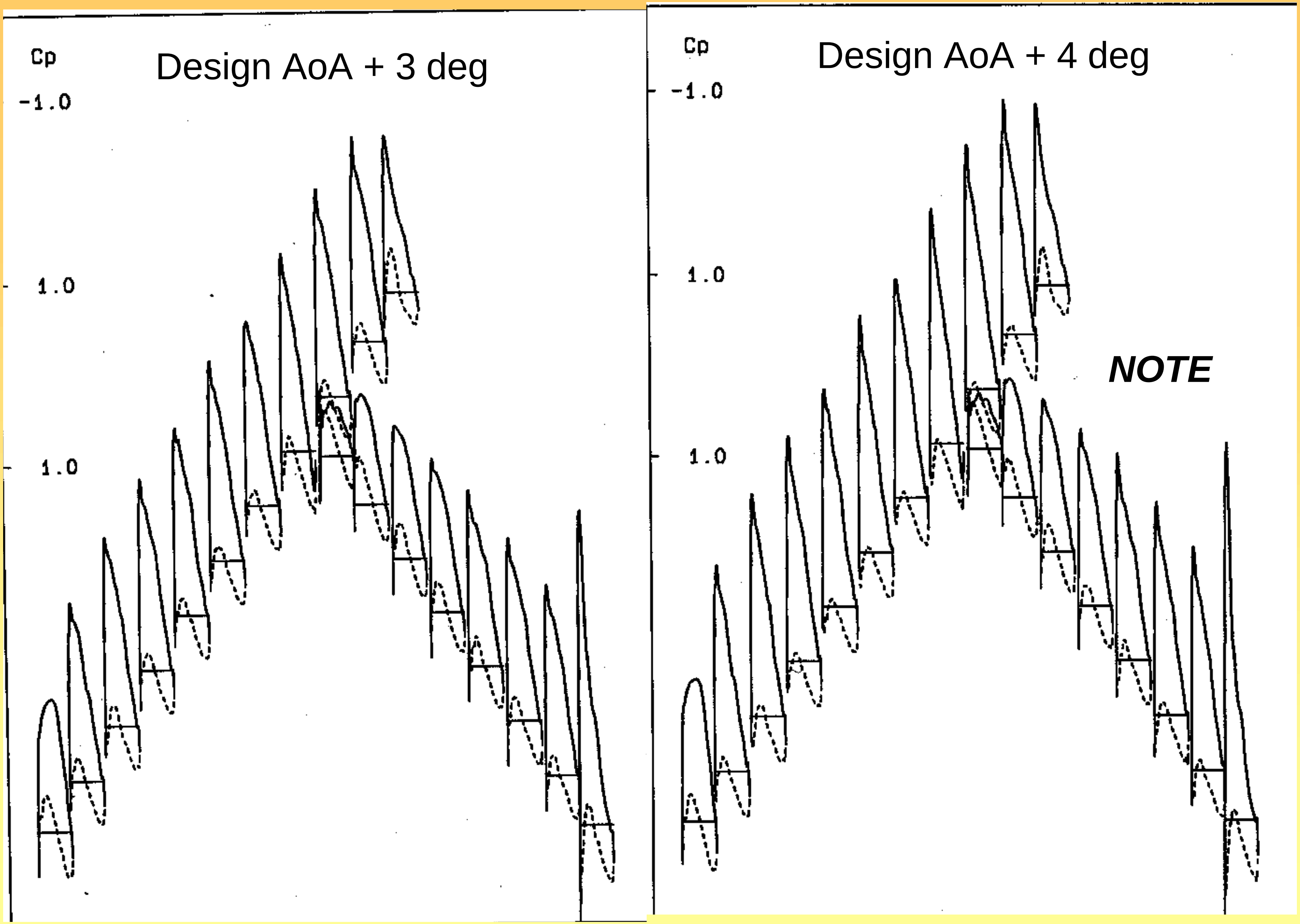
Cp Distbns.

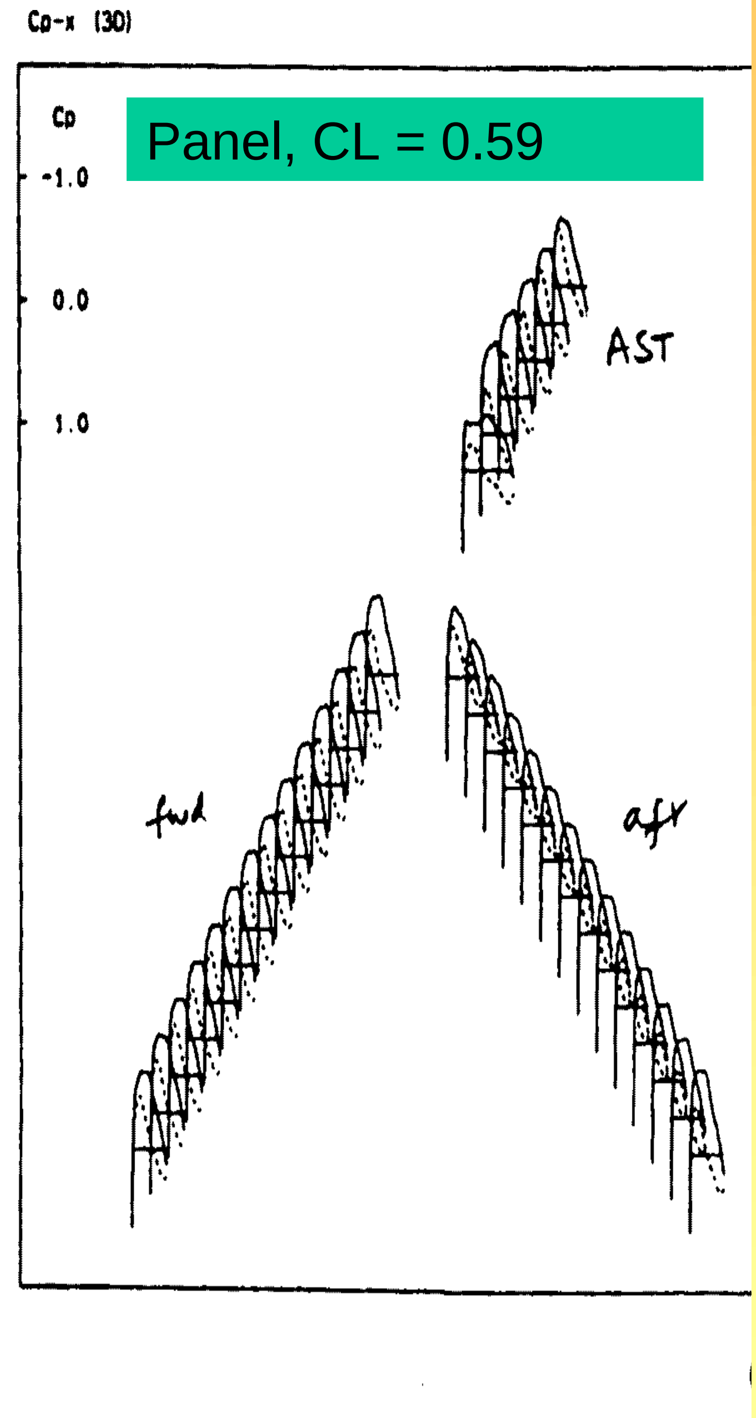
AoA = 3.25, 4.25, 5.25

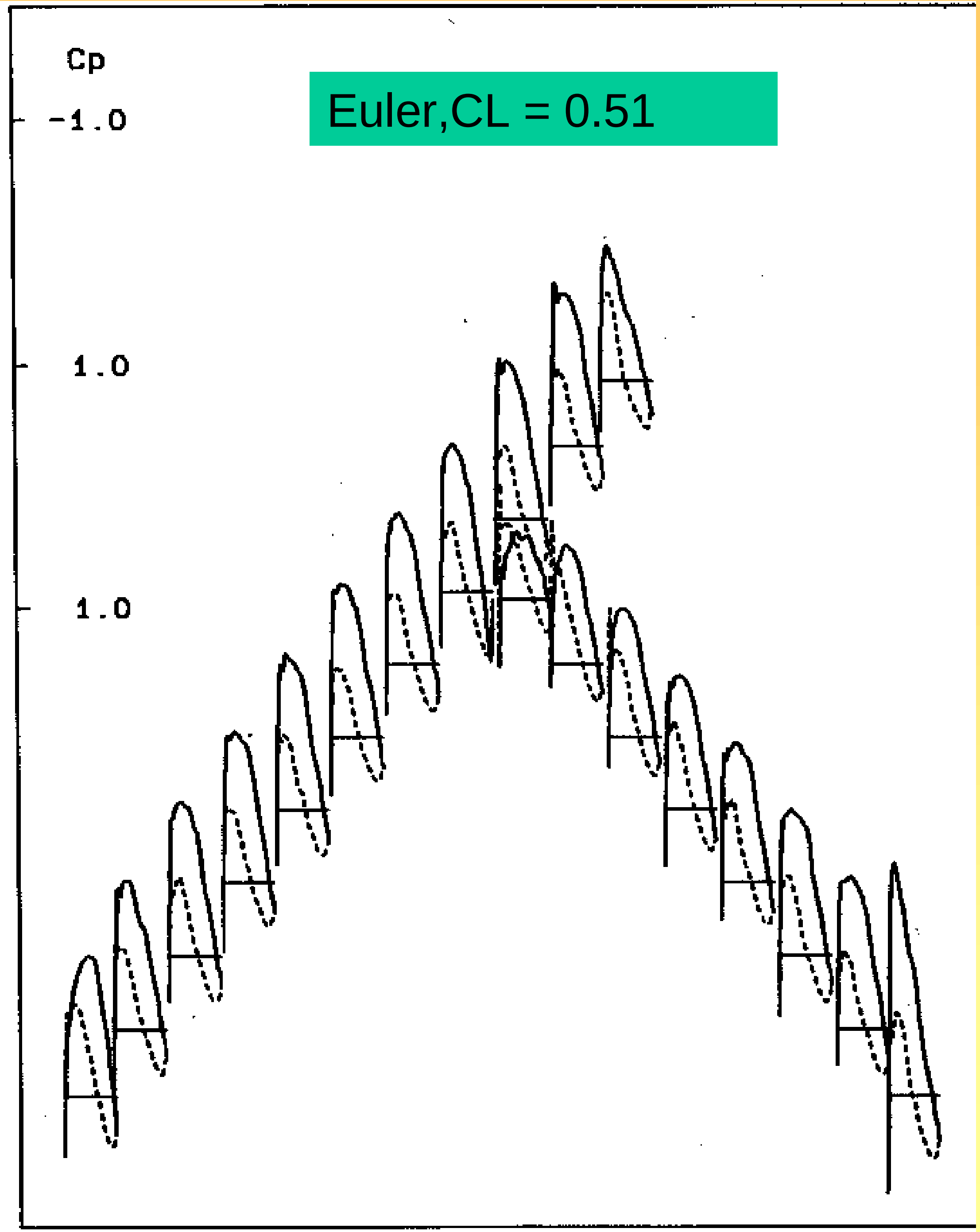


EULER CFD CHECK

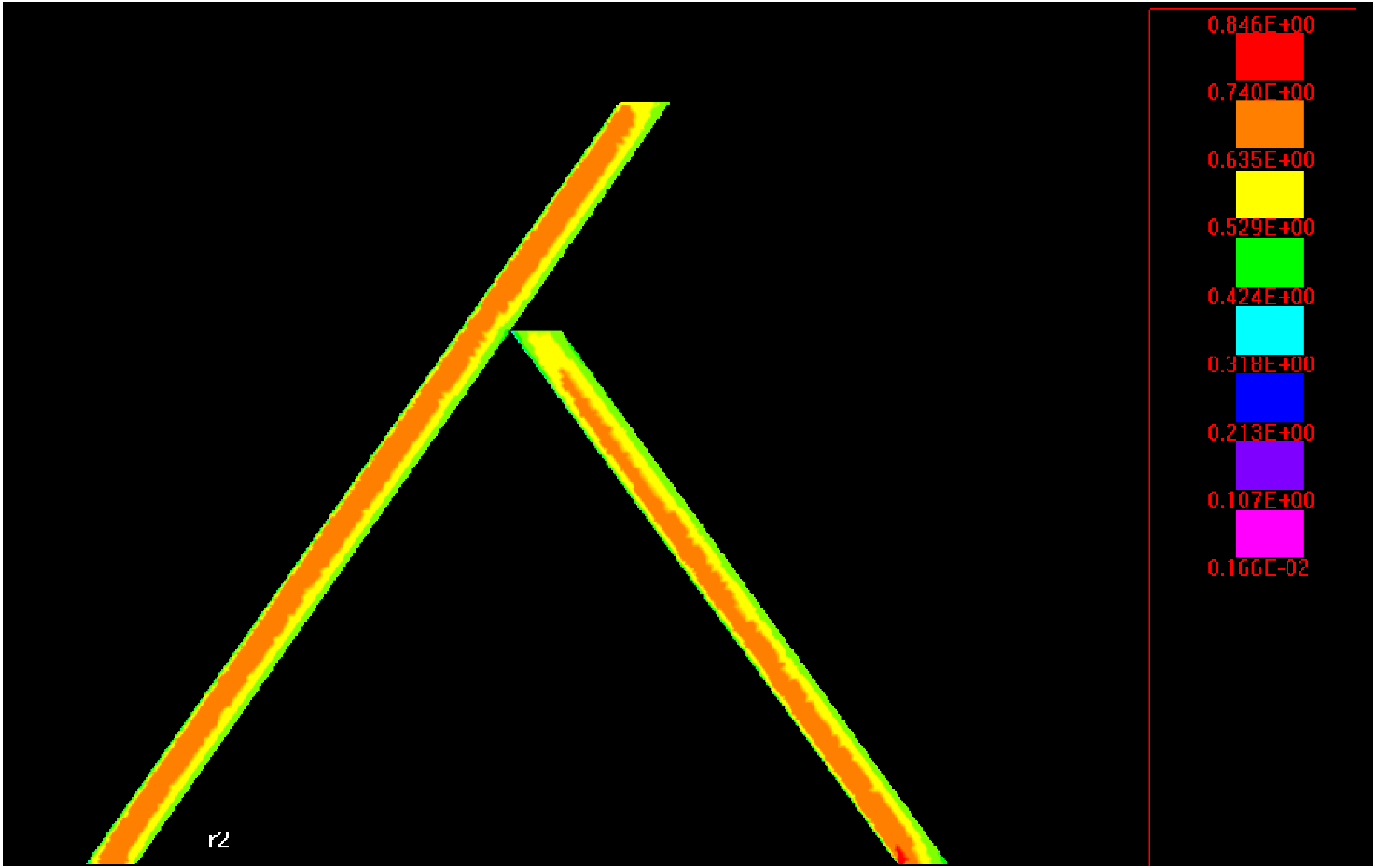
Designed Case & Off-Design look for extreme gradients


Cp
Design AoA + 3 deg
-1.0
1.0
1.0
Cp
Design AoA + 4 deg
-1.0
1.0
1.0
NOTE


Cp-x (30)
Cp
Panel, CL = 0.59
-1.0
0.0
1.0
AST
fwd
aft

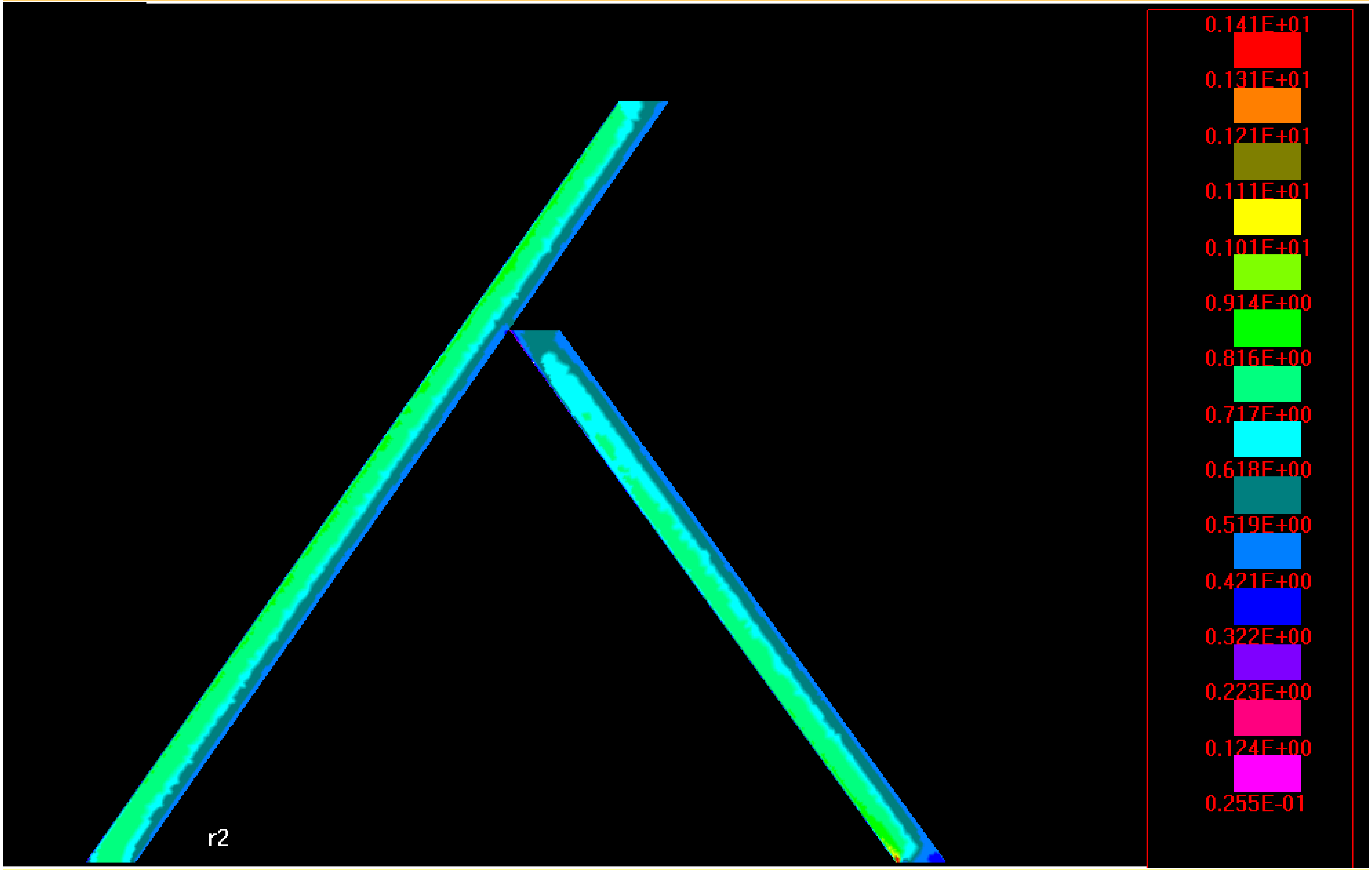

Cp
-1.0
Euler,CL = 0.51
1.0
1.0

Mach no

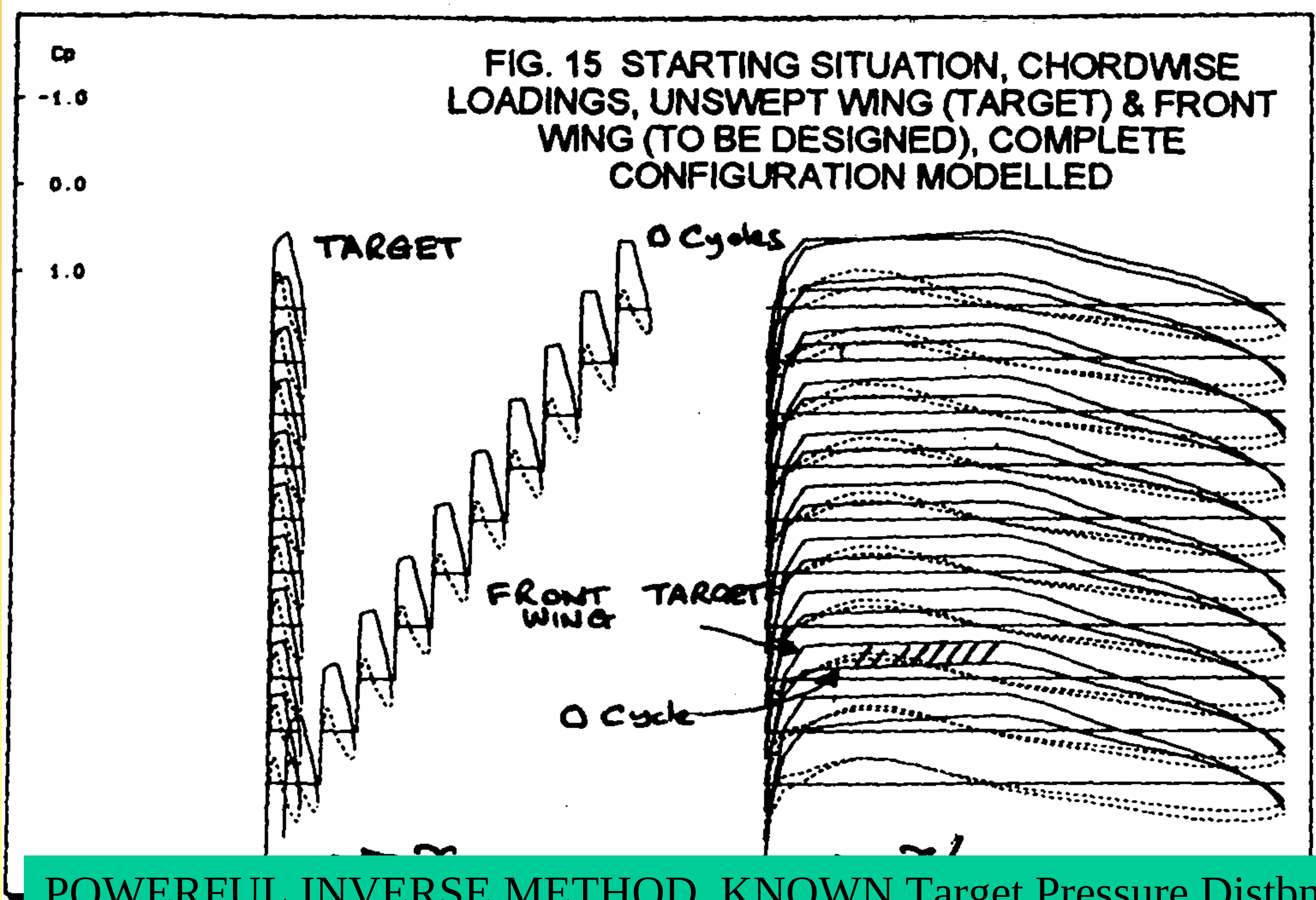


Euler, M=0.6, Design AoA + 0 deg, CL = 0.51, Upper Surface

Mach no.



Euler, M=0.6, Design AoA + 4 deg, CL = 1.08, Upper Surface



POWERFUL INVERSE METHOD, KNOWN Target Pressure Distbn. "Supplanted" on a GIVEN WING

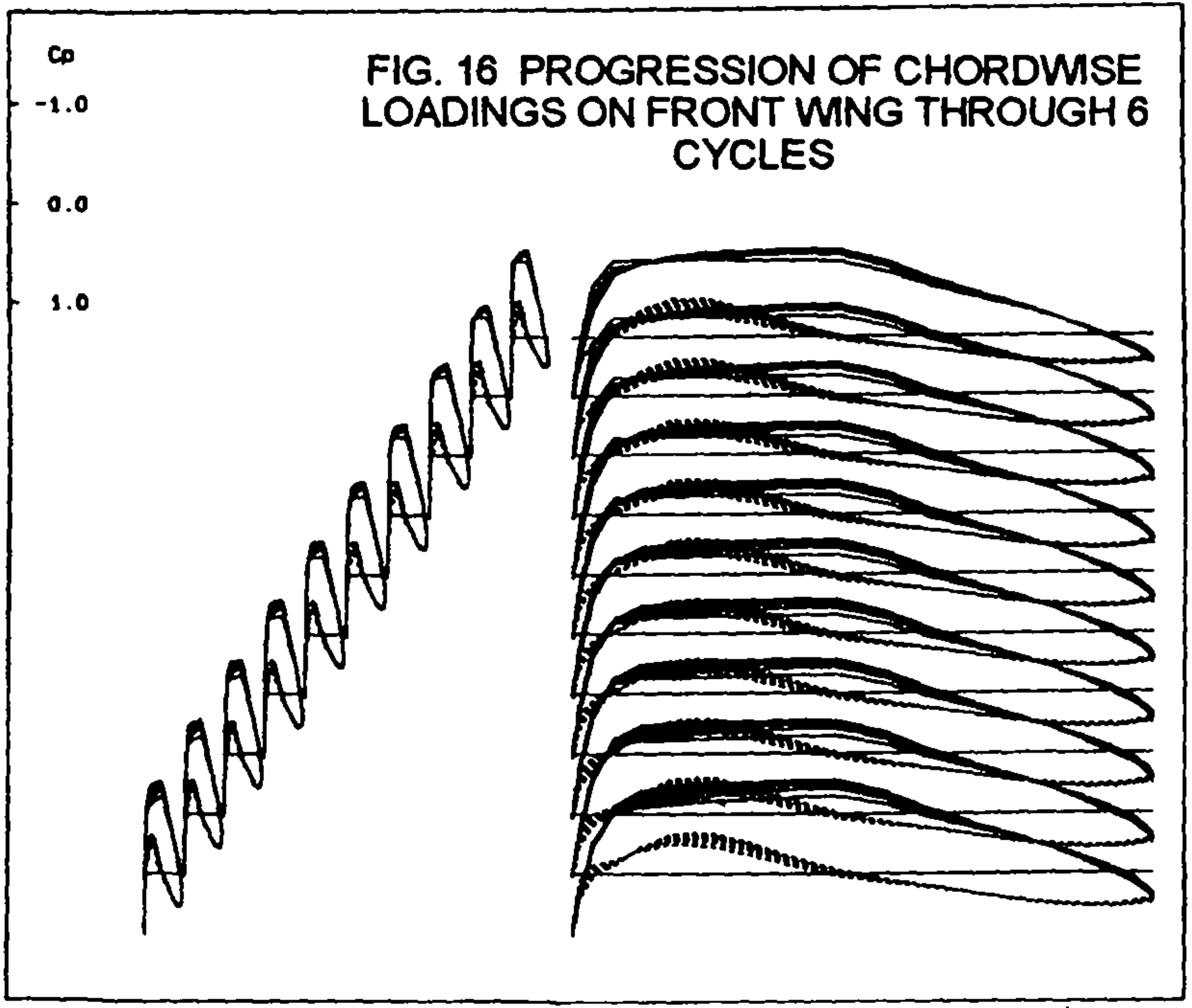
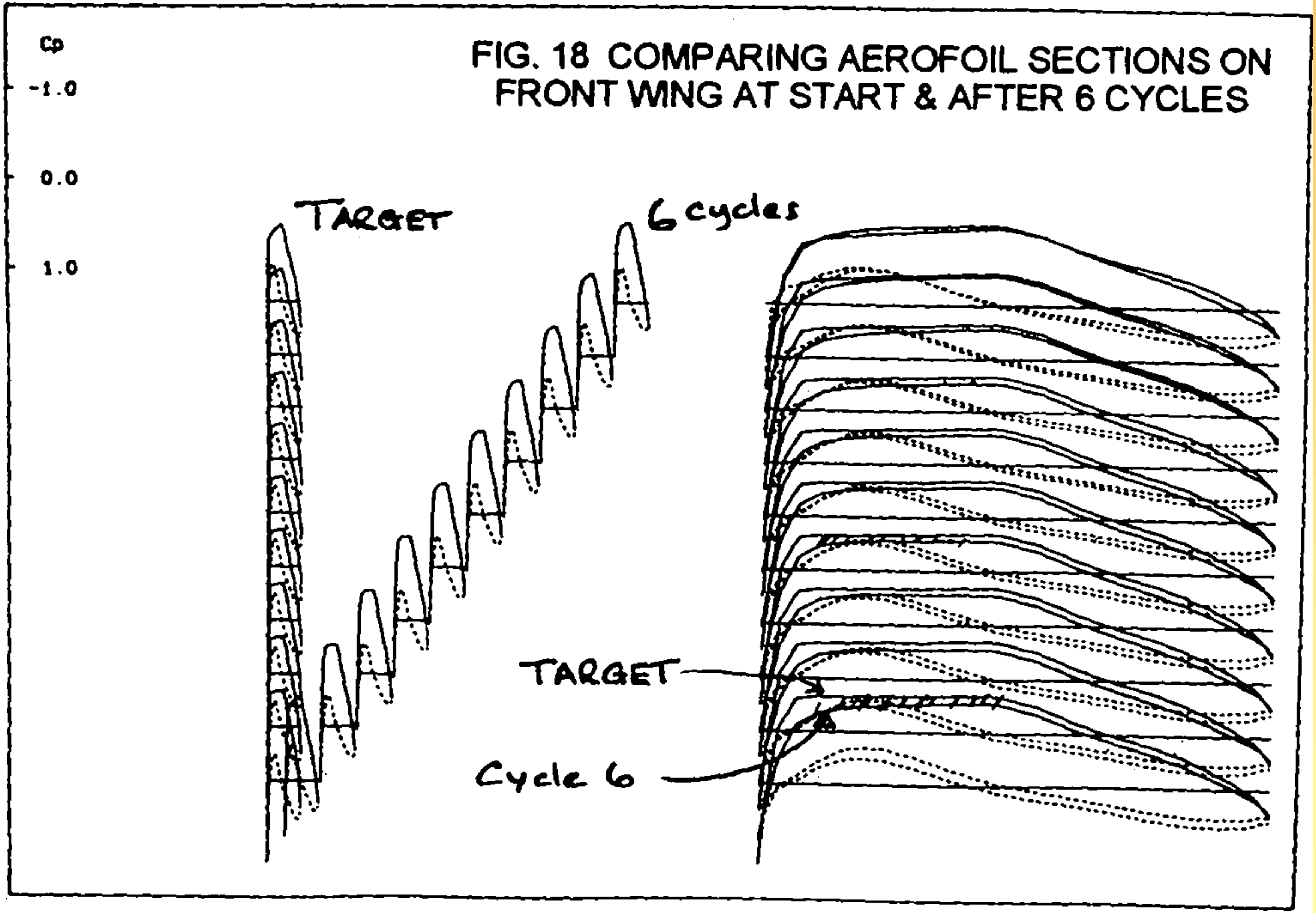
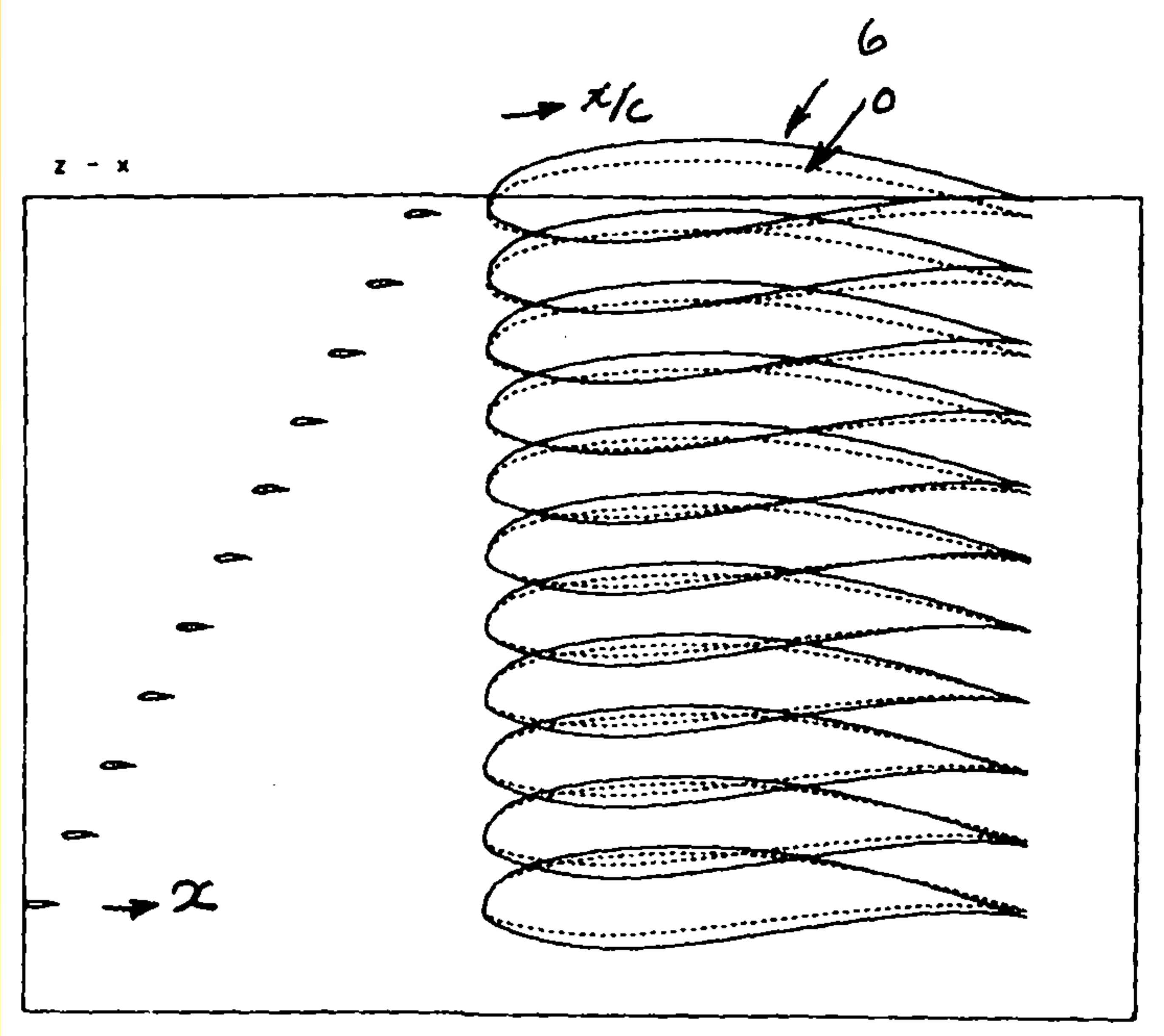


FIG. 16 PROGRESSION OF CHORDWISE LOADINGS ON FRONT WING THROUGH 6 CYCLES

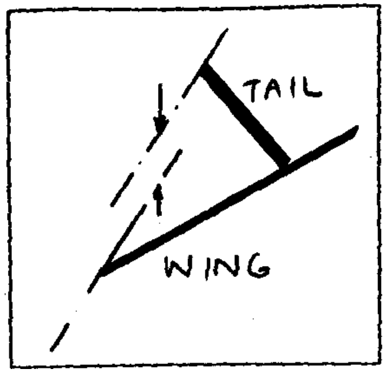


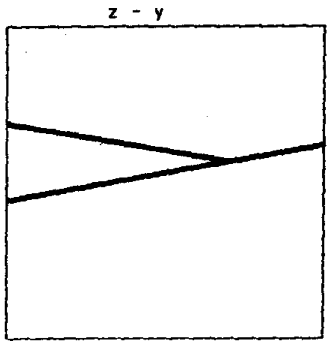
Cp
-1.0
0.0
1.0
FIG. 18 COMPARING AEROFOIL SECTIONS ON FRONT WING AT START & AFTER 6 CYCLES
TARGET
6 cycles
TARGET
Cycle 6

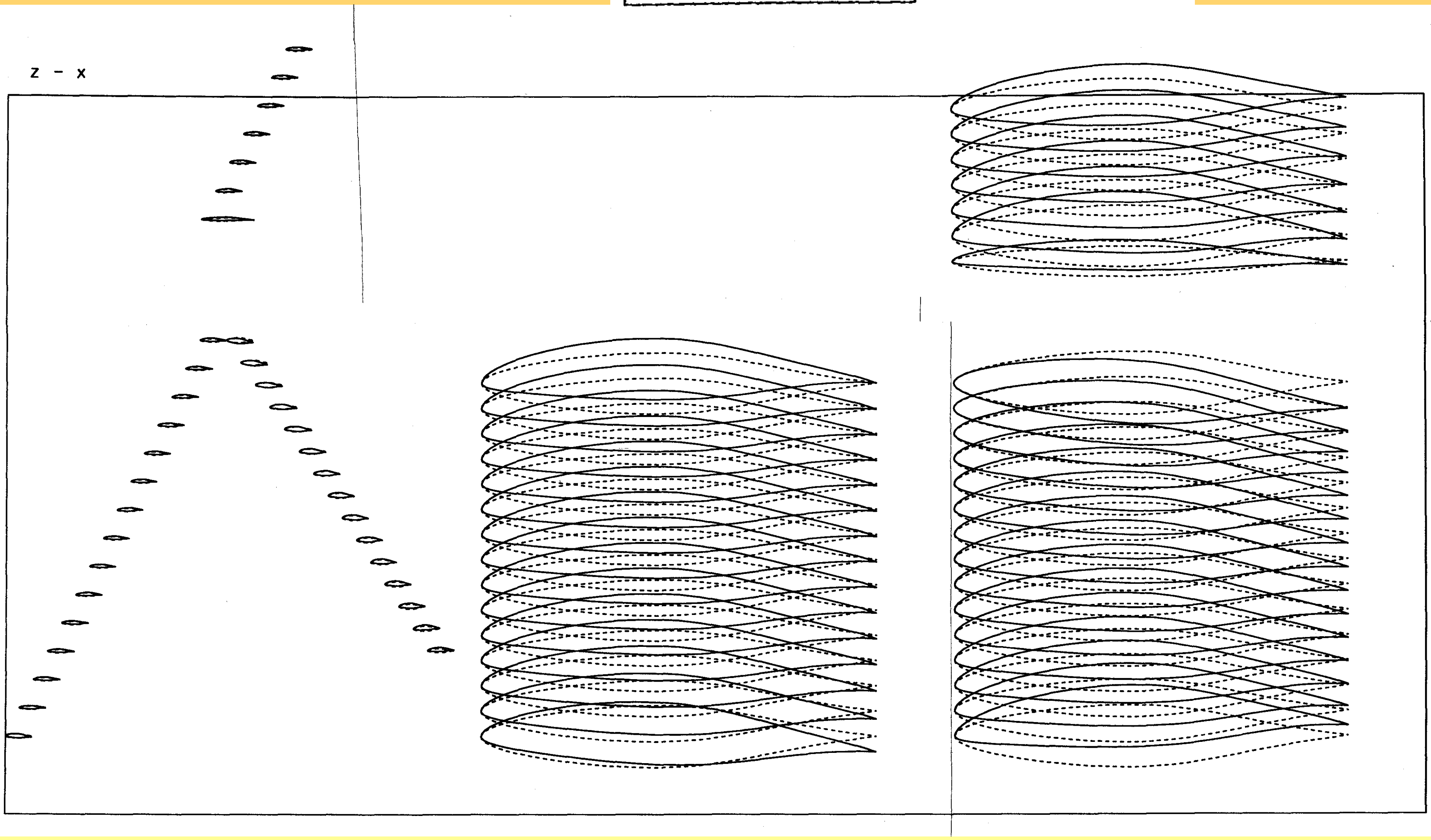
COMPARING AEROFOIL SECTIONS ON FRONT WING AT START & AFTER 6 CYCLES (WING AND TAIL BOTH MODELLED)

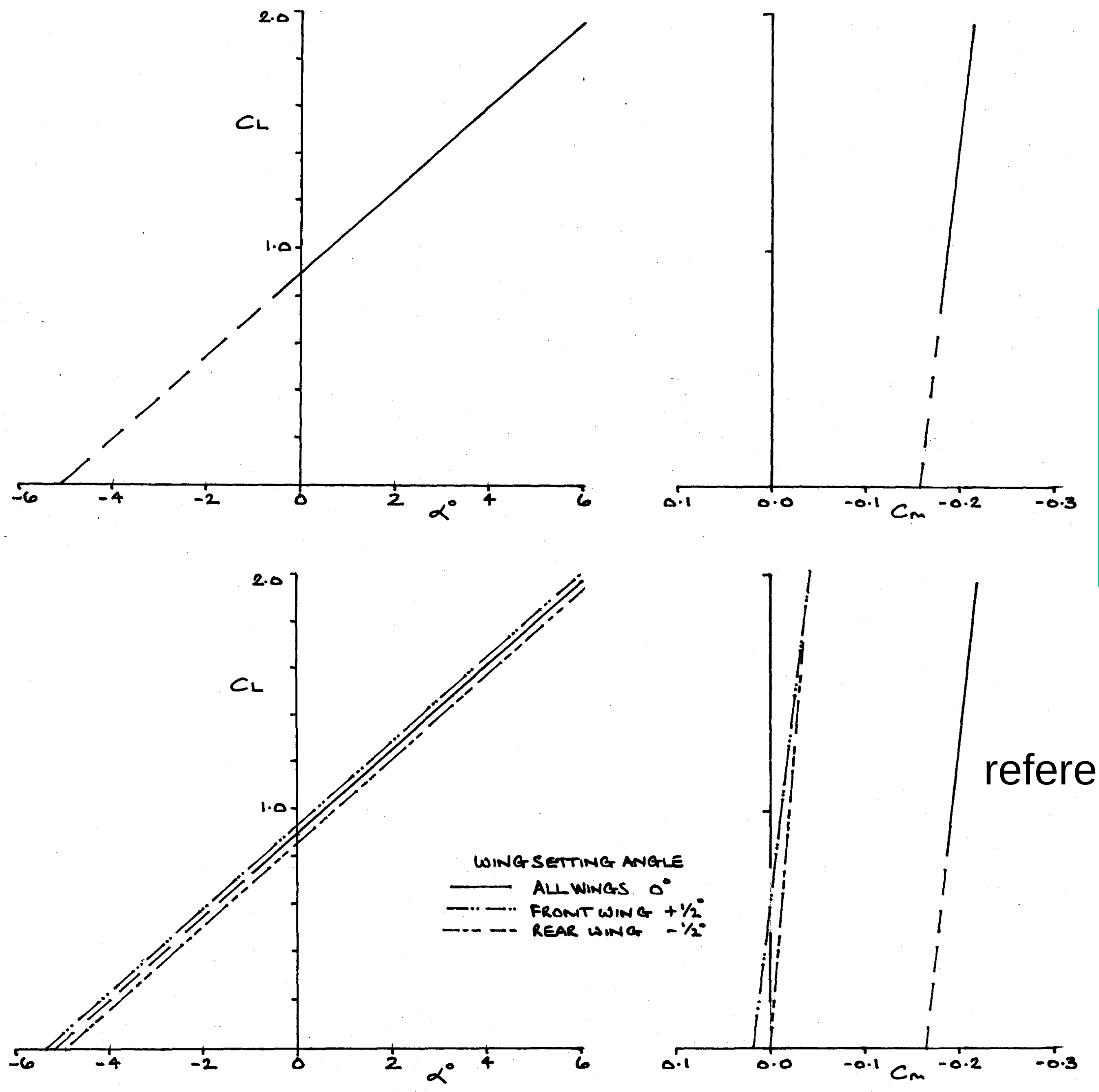


Laminar AT1



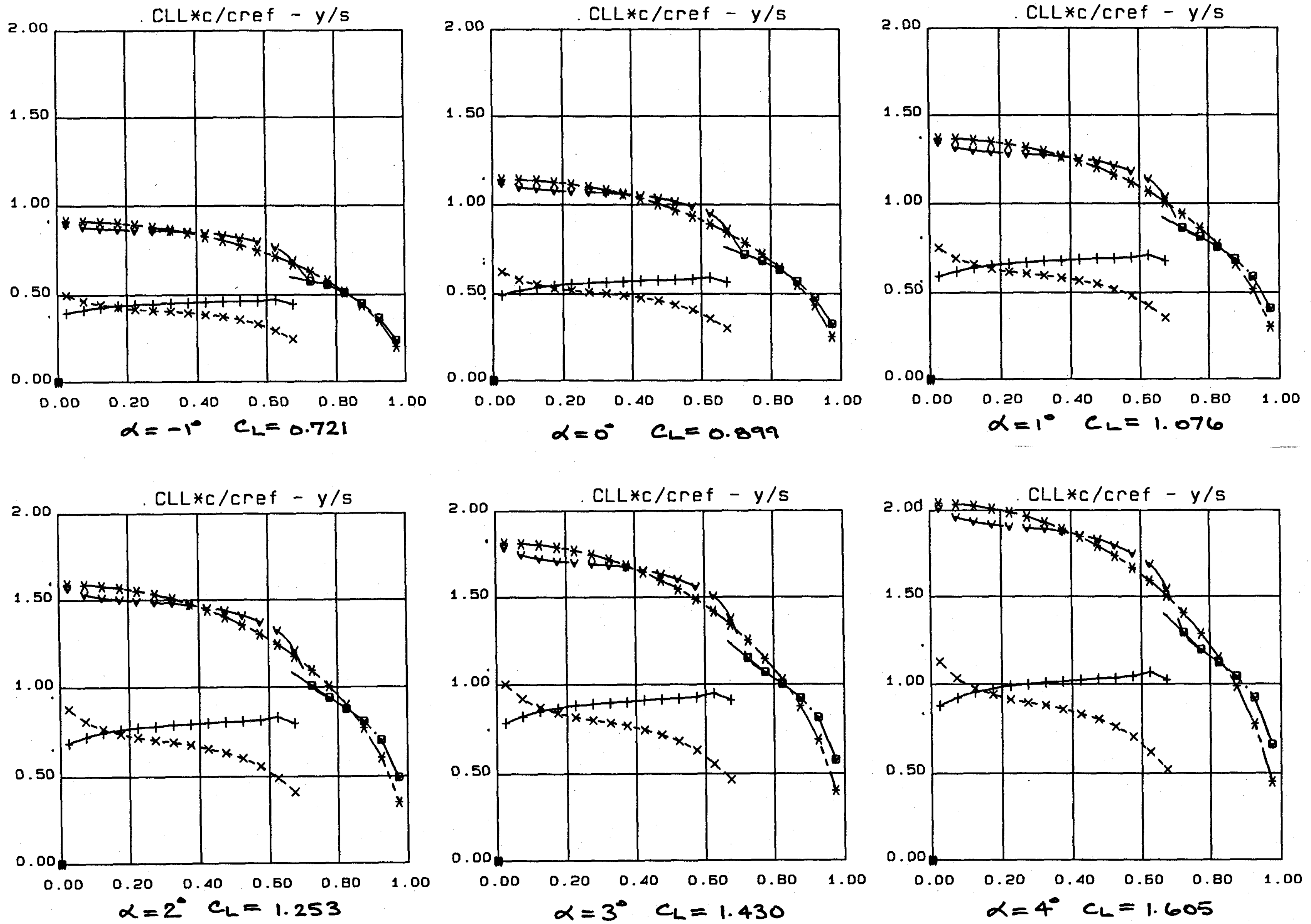




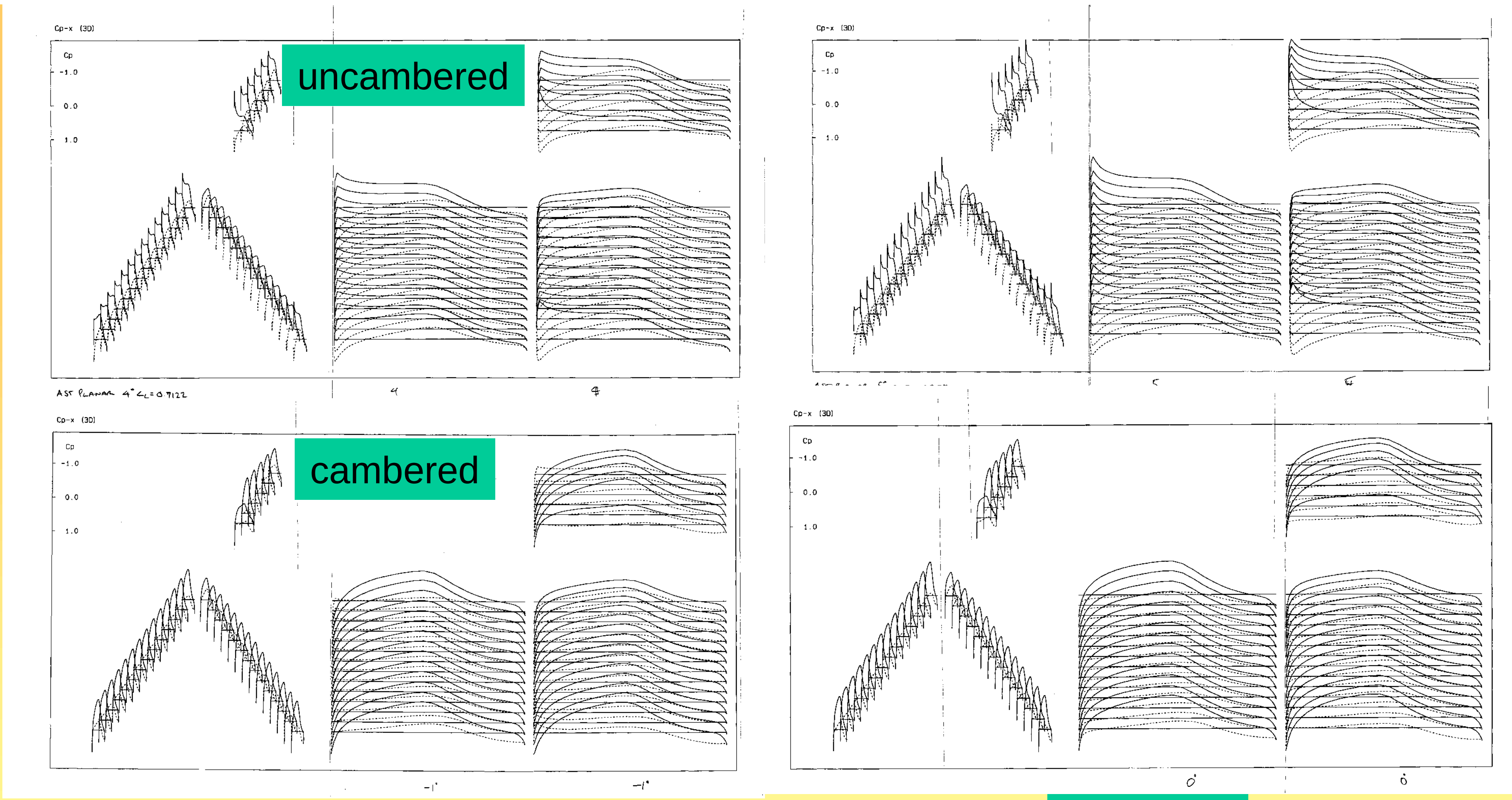


CL & Cm Reference & Control due to 0.5 deg setting angle changes

reference



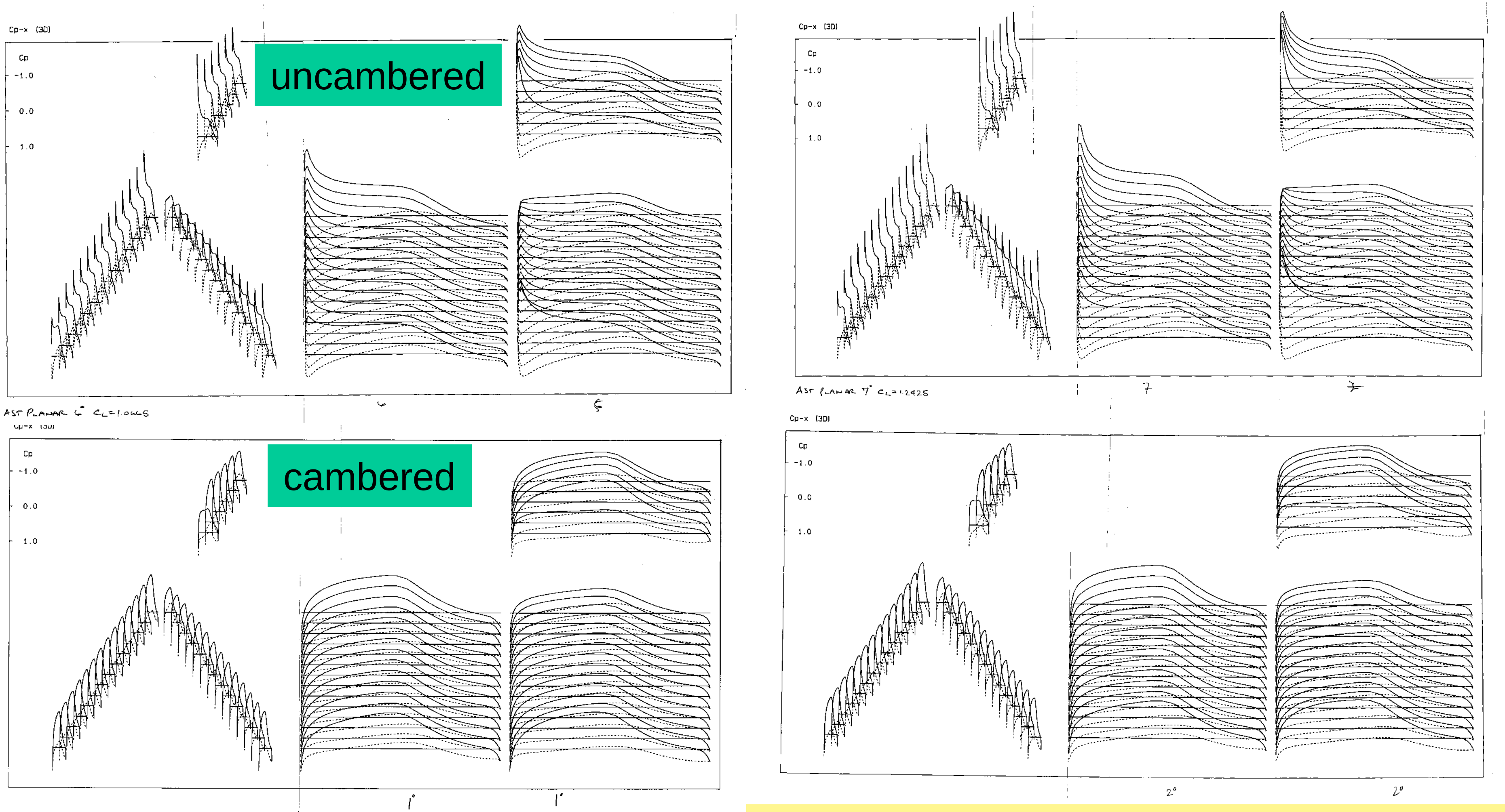
SPANWISE LOADINGS AT Mach 0.6, CL=0.72, 0.9,1.07,1.25.1.43,1.6



CL=0.72

CL=0.9

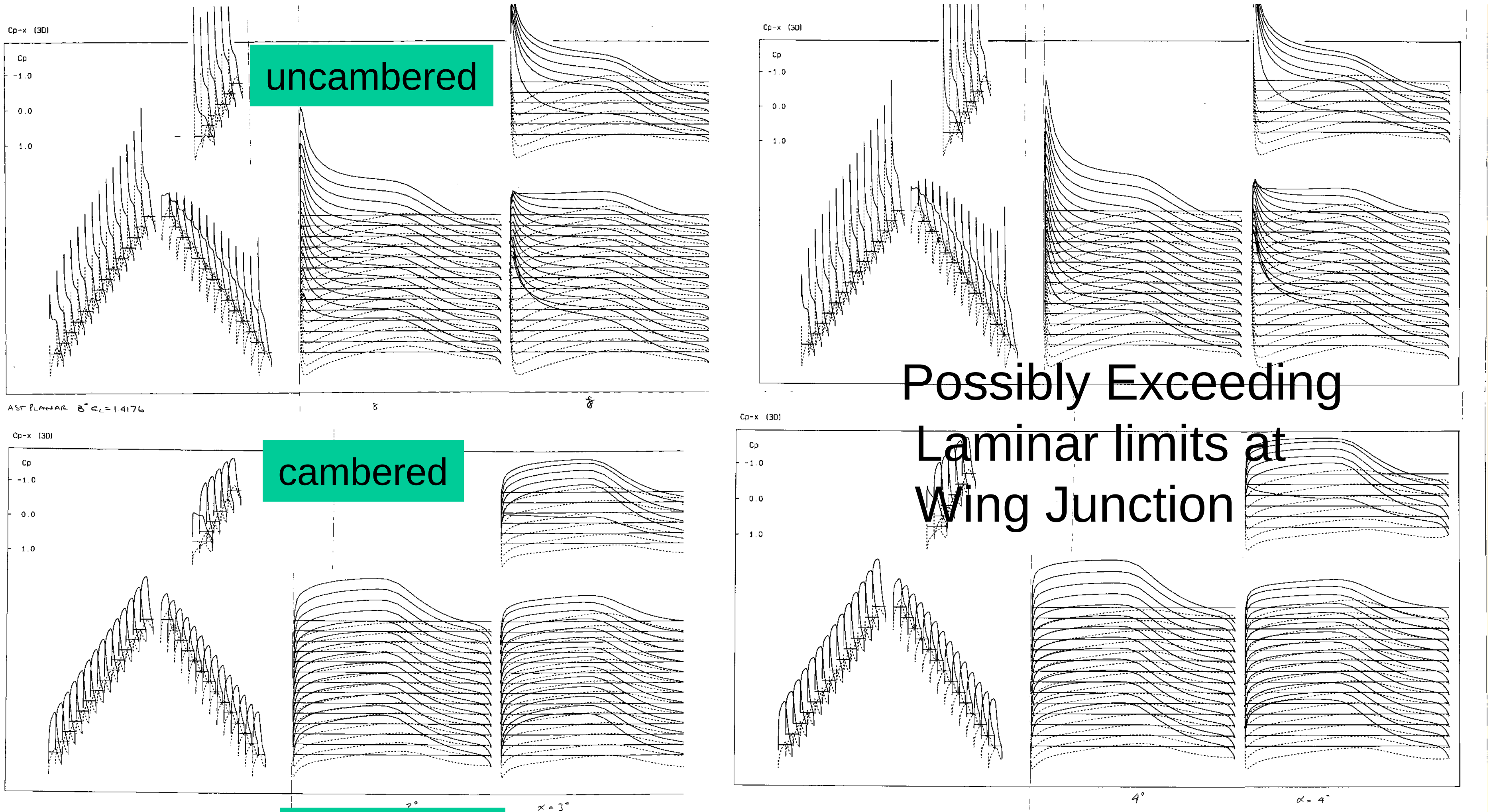
COMPARING UNCAMBERED & DESIGNED CONFIGS AT SAME CL VALUES



CL=1.07

CL=1.25

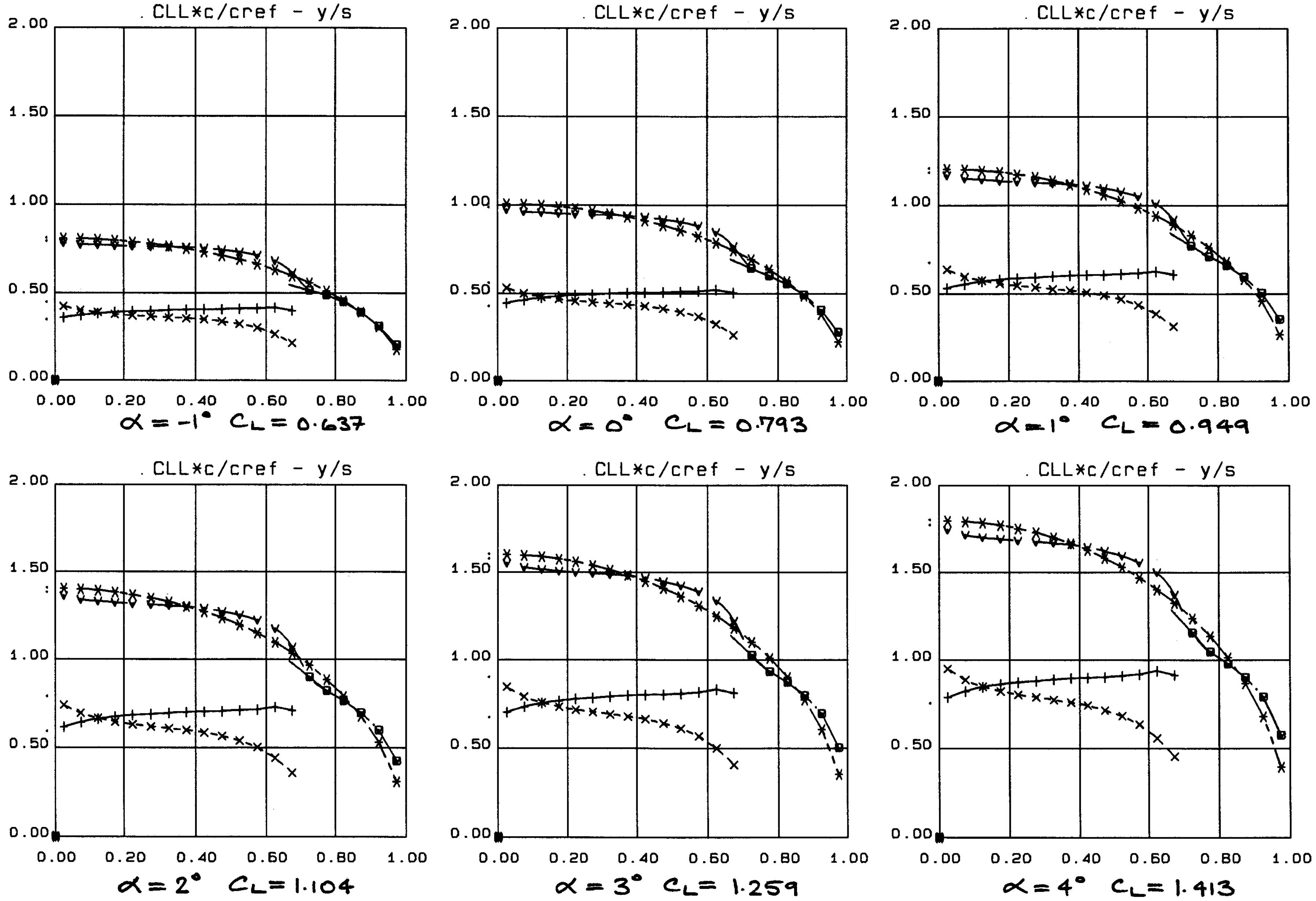
COMPARING UNCAMBERED & DESIGNED CONFIGS AT SAME CL VALUES



CL=1.43

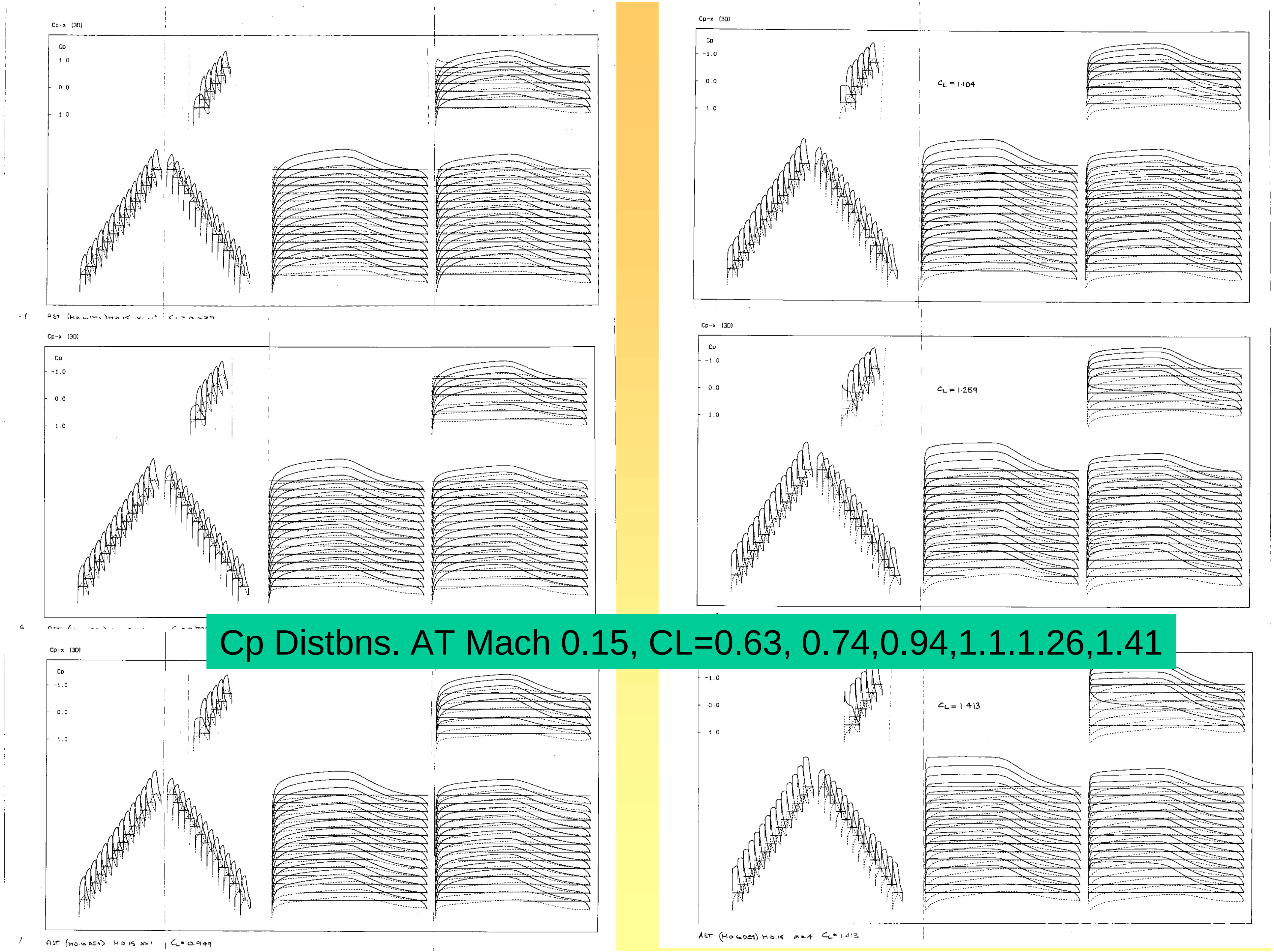
CL=1.6

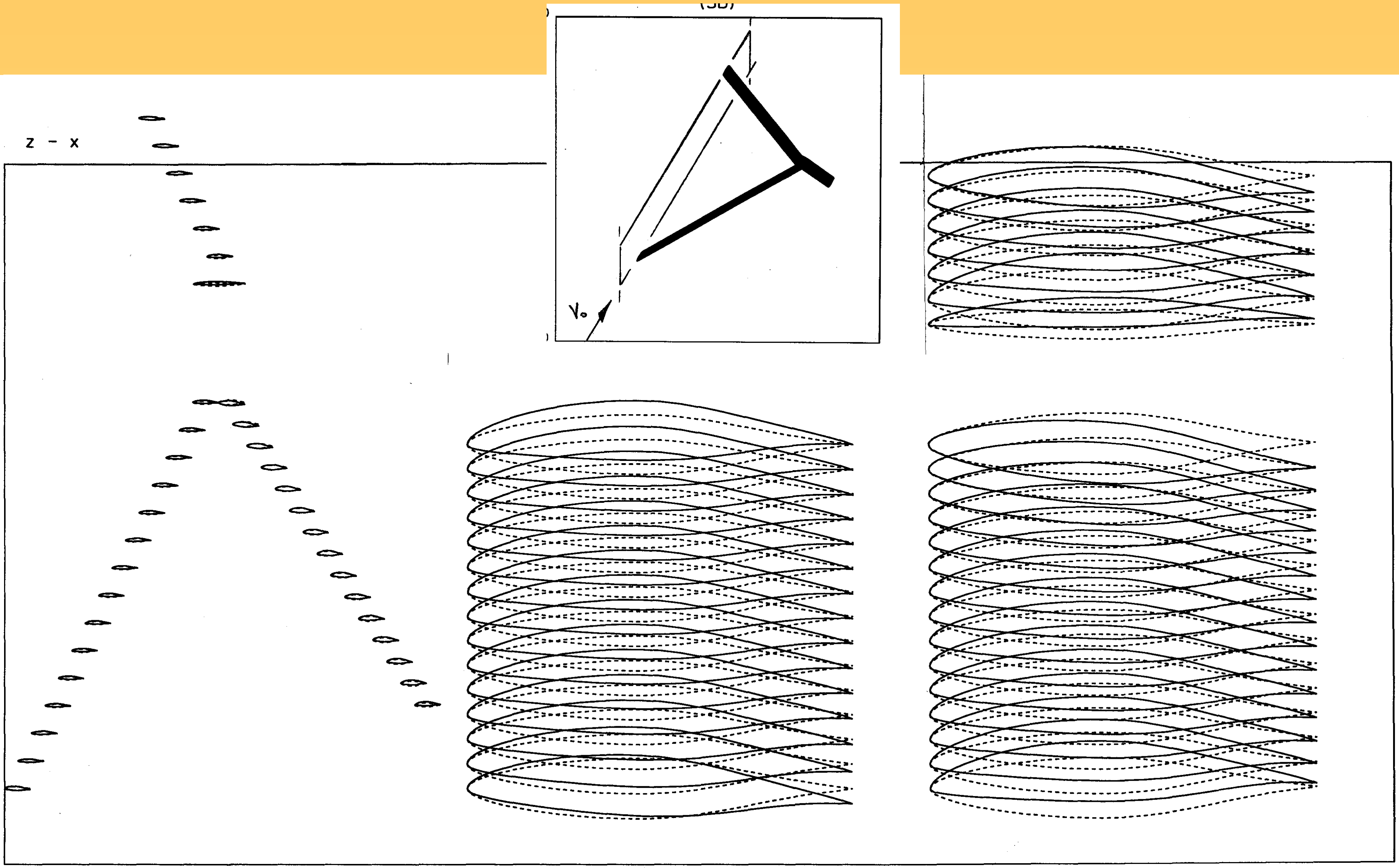
COMPARING UNCAMBERED & DESIGNED CONFIGS AT SAME CL VALUES



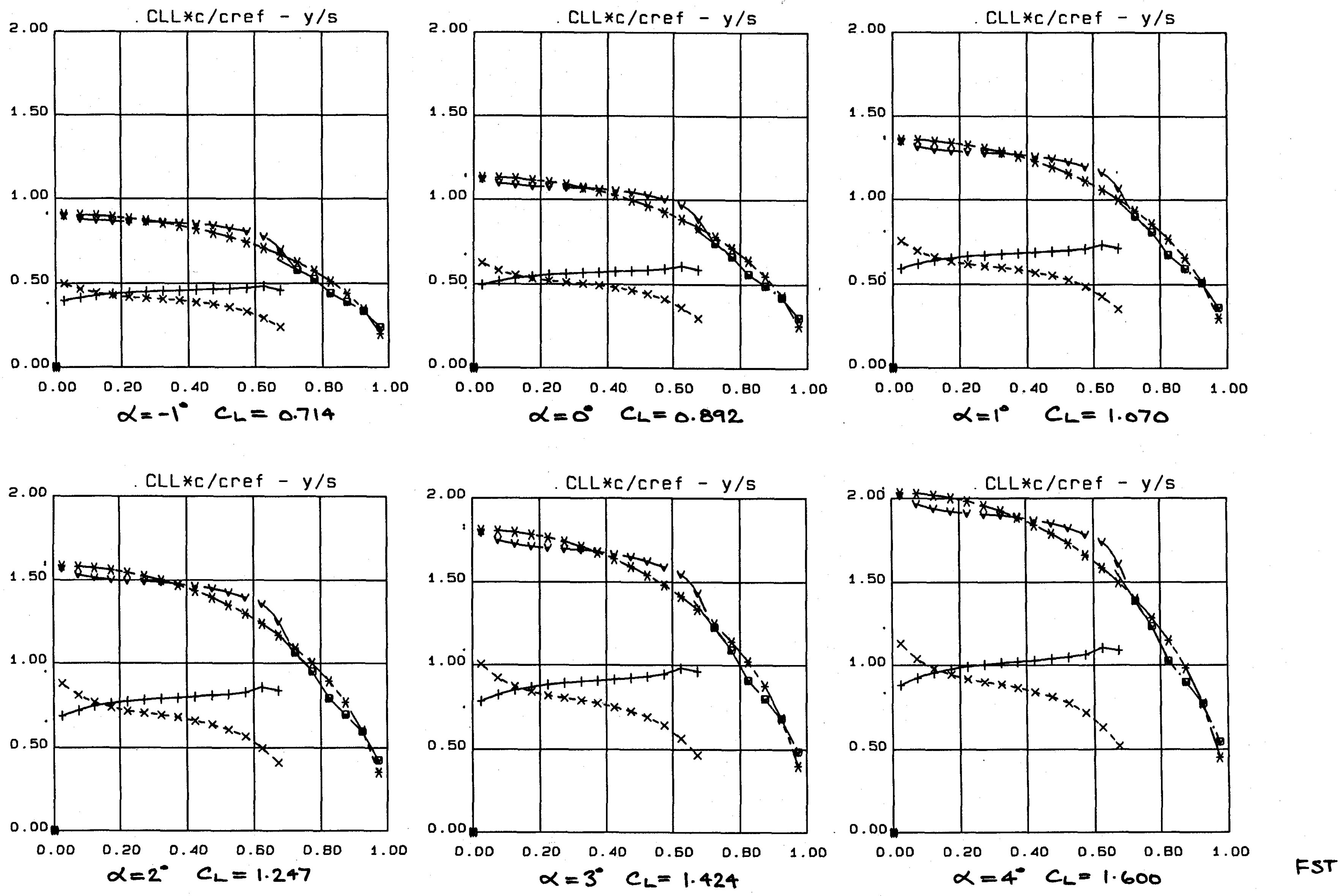
SPANWISE LOADINGS AT Mach 0.15, CL=0.63, 0.74,0.94,1.1.1.26,1.41

Cp Distbns. AT Mach 0.15, CL=0.63, 0.74,0.94,1.1.1.26,1.41

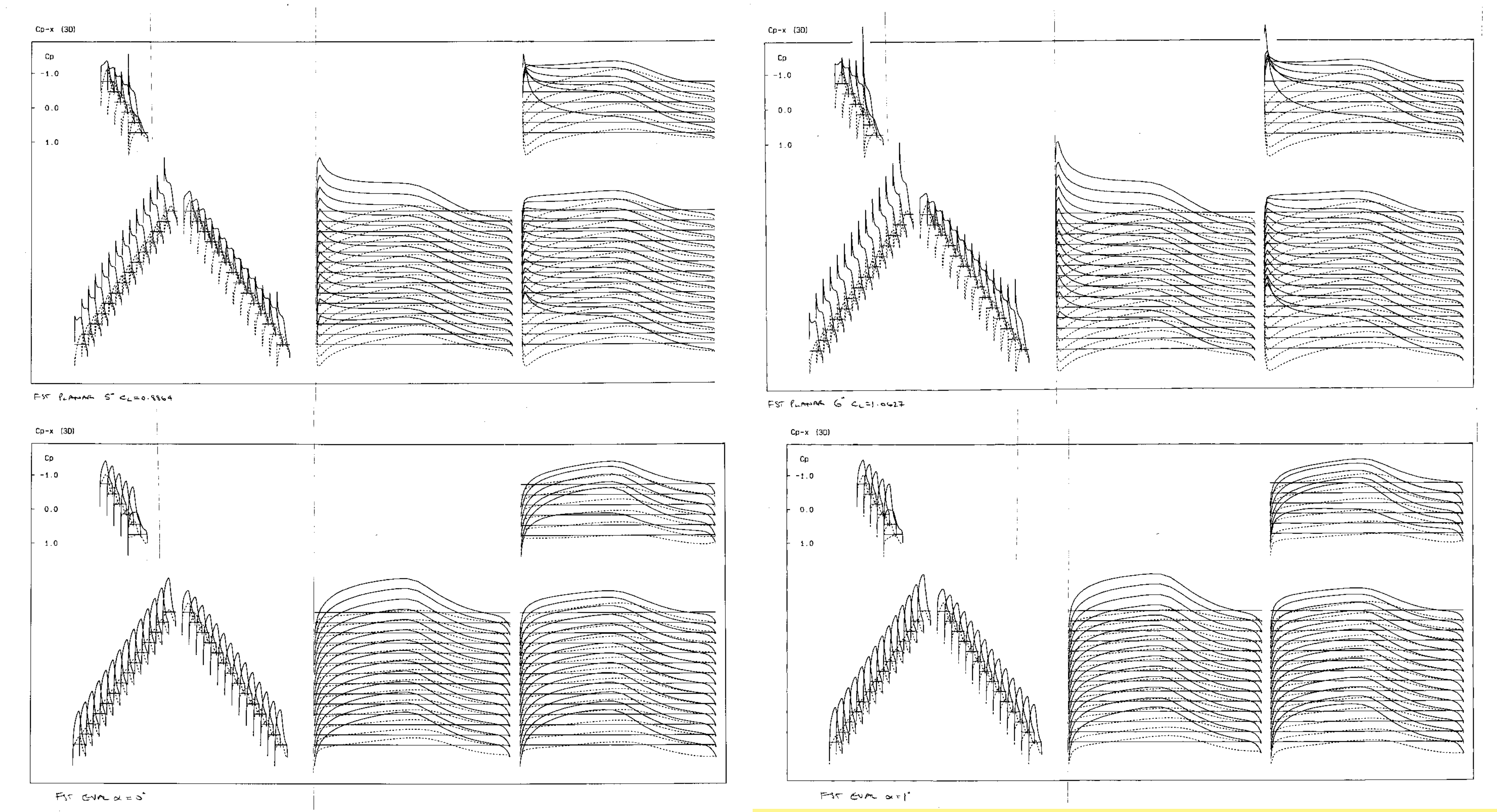




Forward Swept Tip FT1 Laminar



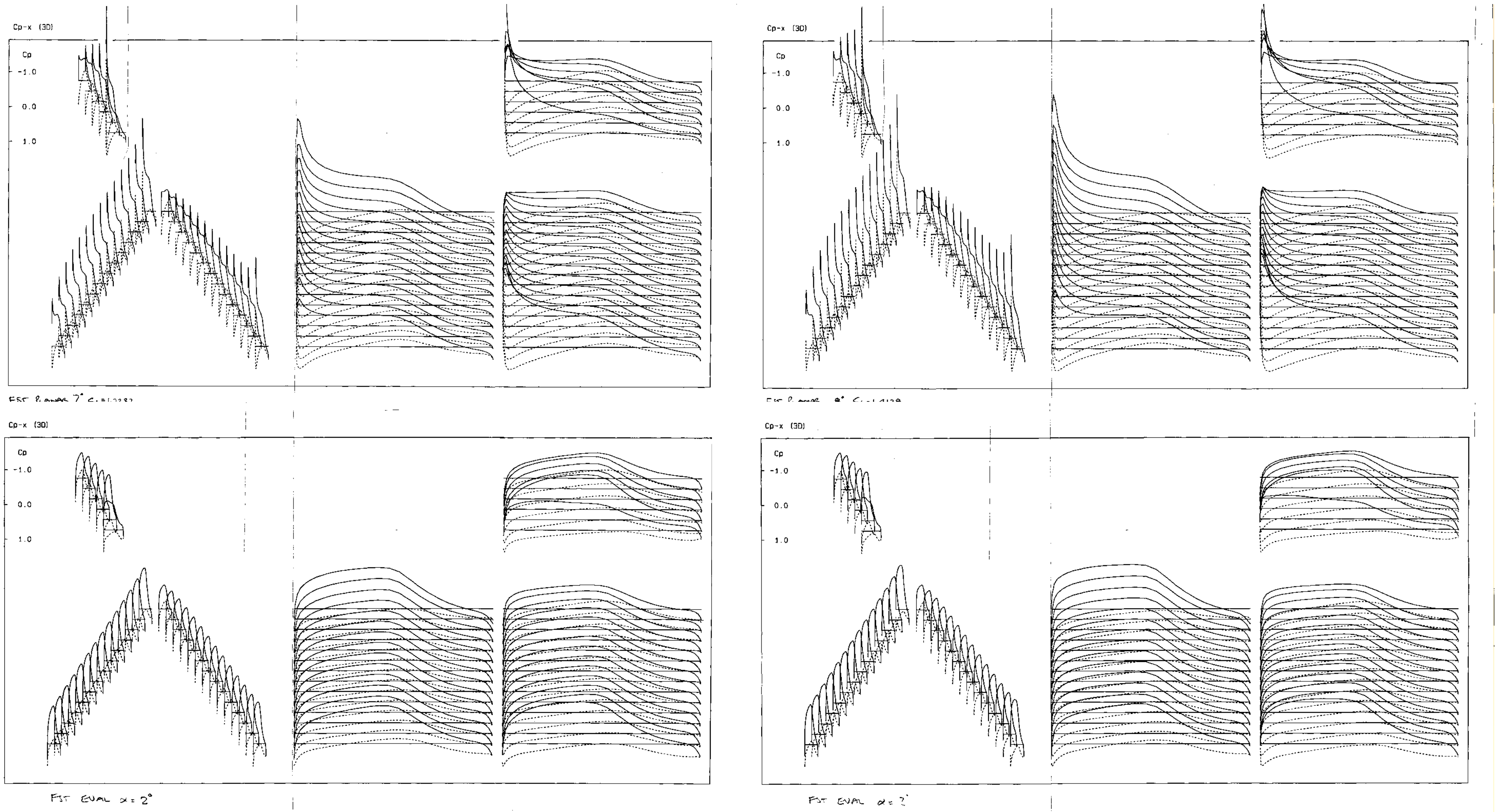
SPANWISE LOADINGS AT Mach 0.6, CL=0.72, 0.9,1.07,1.24.1.43,1.6



CL=0.9

CL=1.07

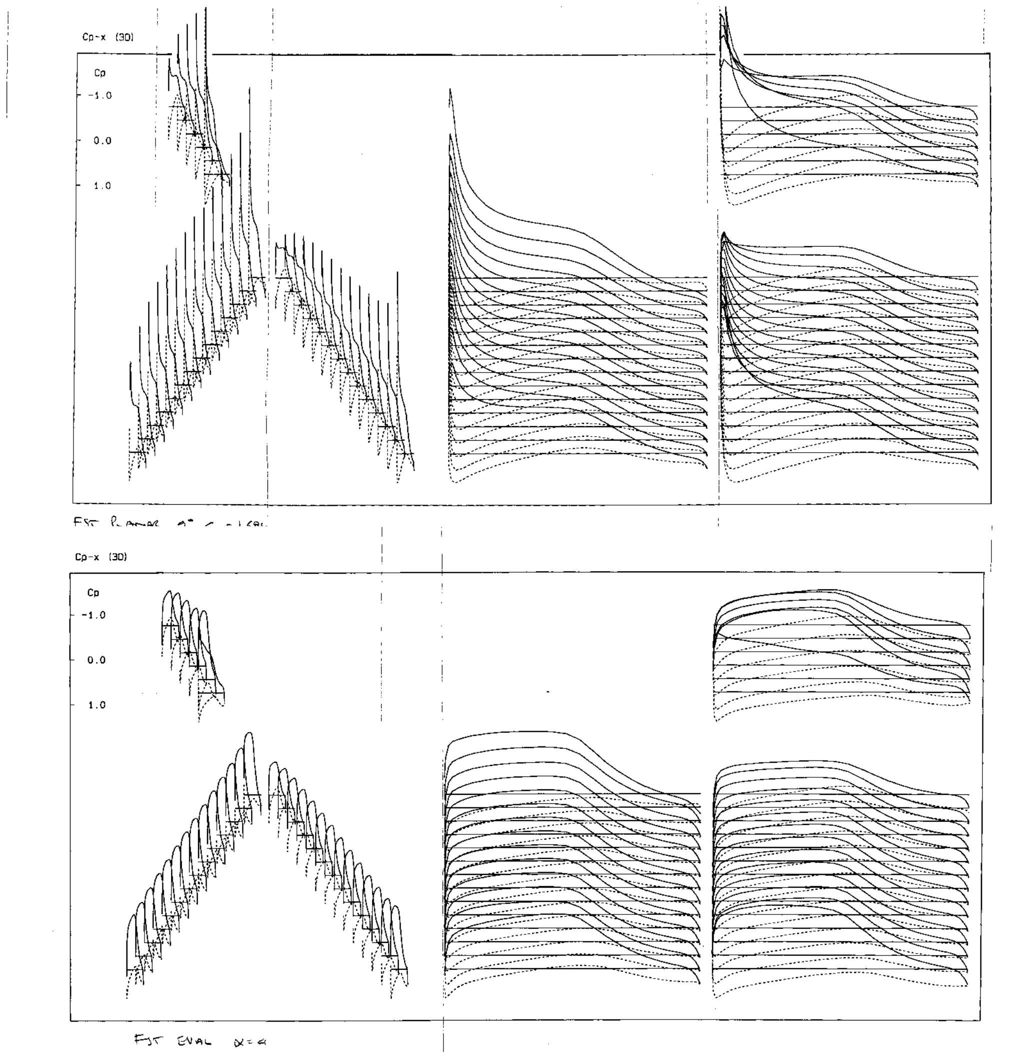
COMPARING UNCAMBERED & DESIGNED CONFIGS AT SAME CL VALUES



CL=1.24

CL=1.43

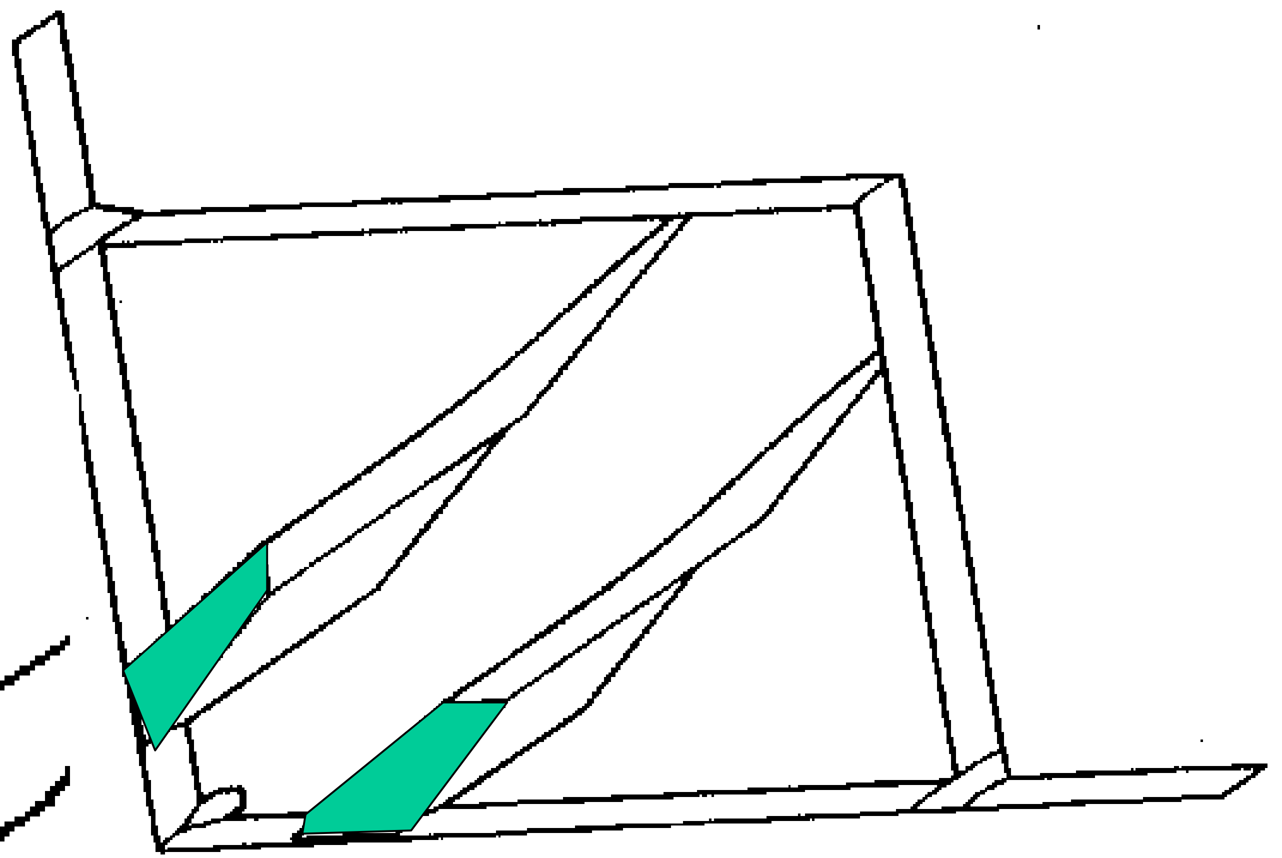
COMPARING UNCAMBERED & DESIGNED CONFIGS AT SAME CL VALUES

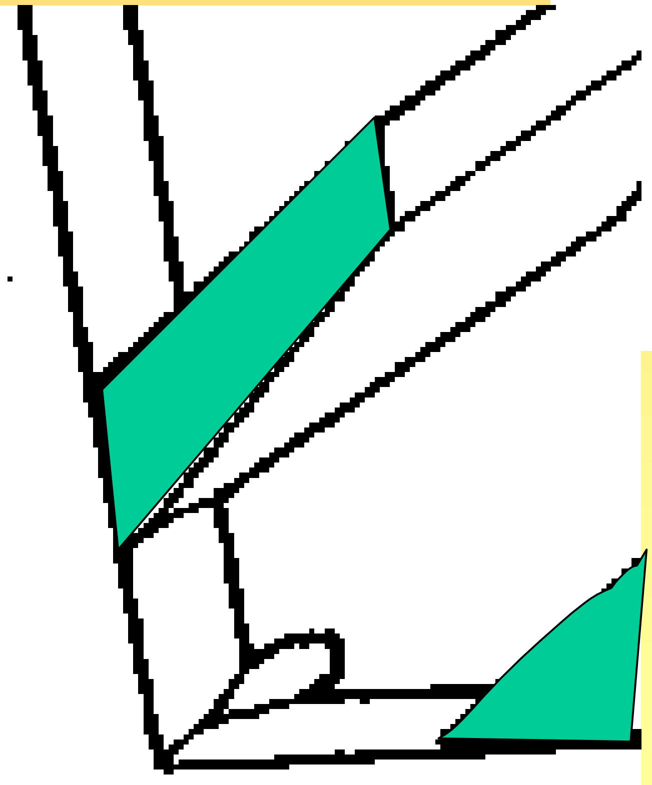


Possibly Exceeding
Laminar limits at
Wing Junction

CL=1.6

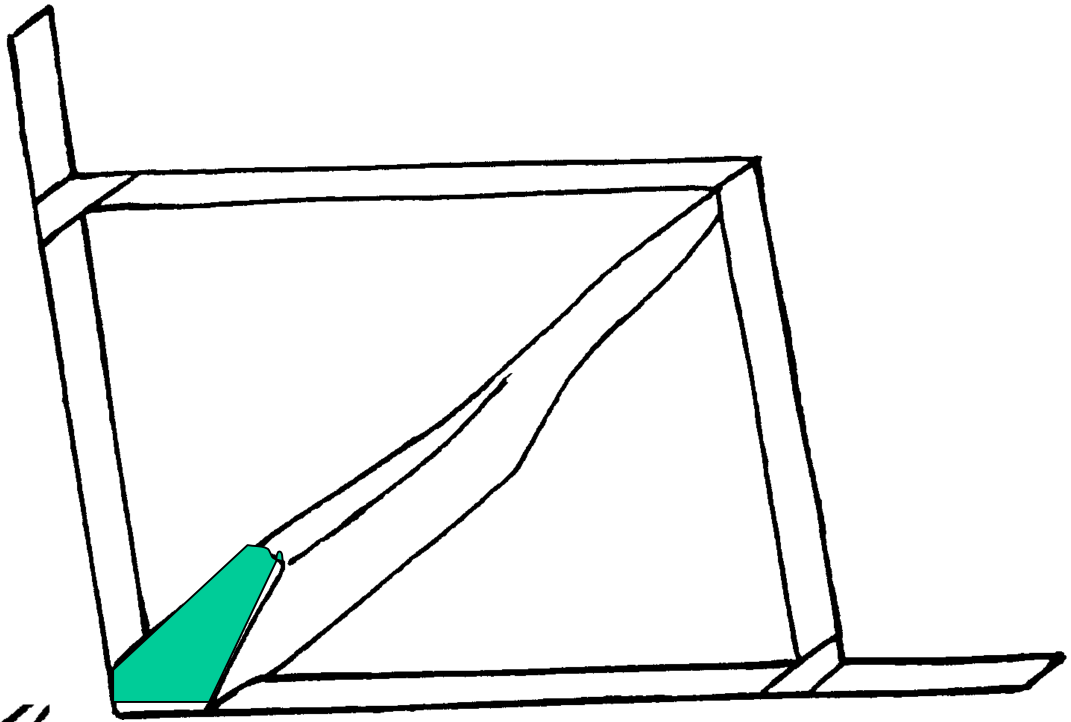
COMPARING UNCAMBERED & DESIGNED CONFIGS AT SAME CL VALUES

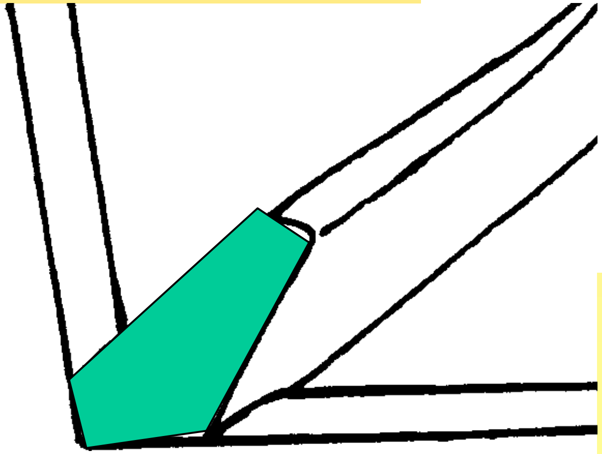




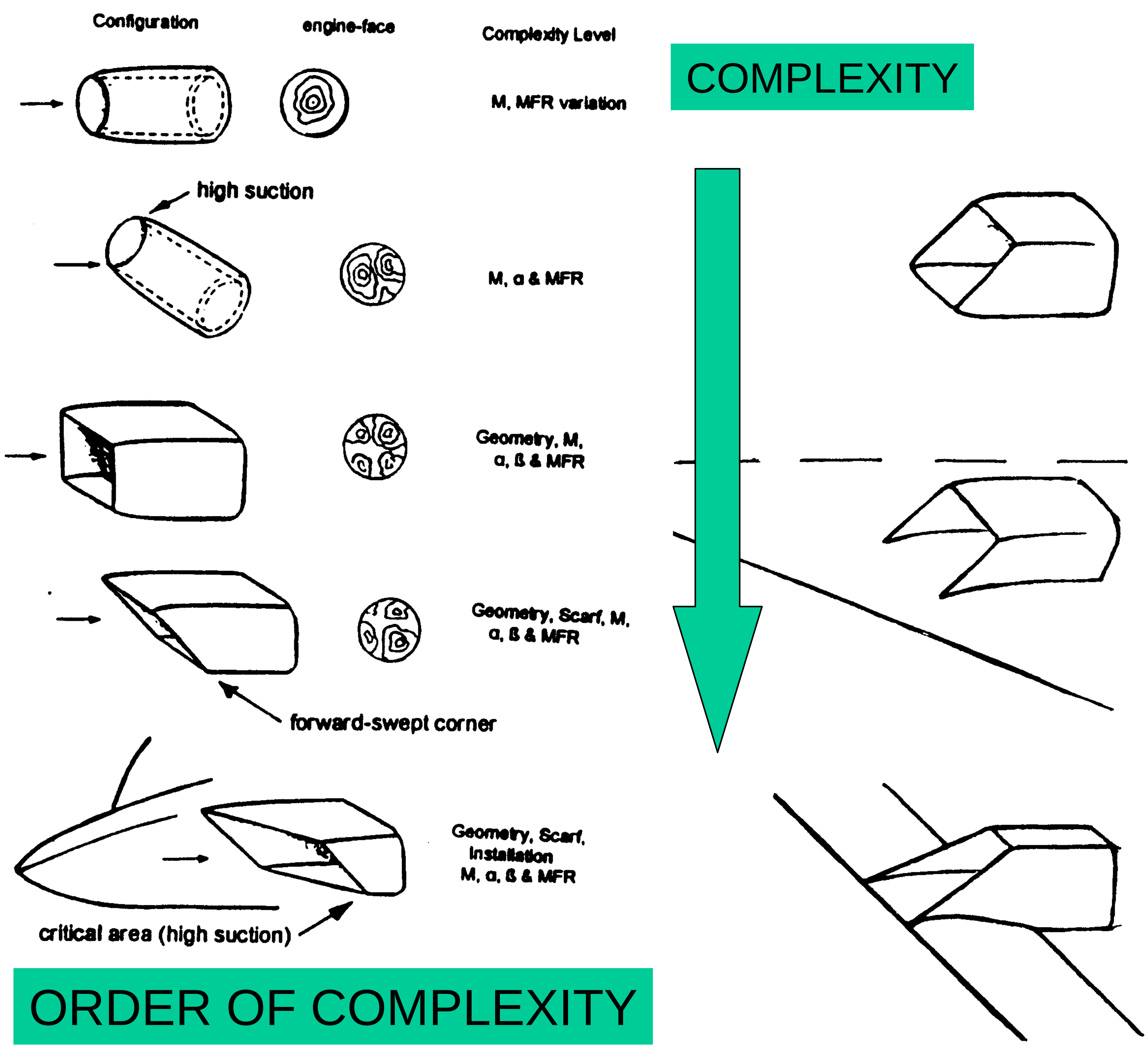
Twin Fuselage intakes

Propulsion Considerations

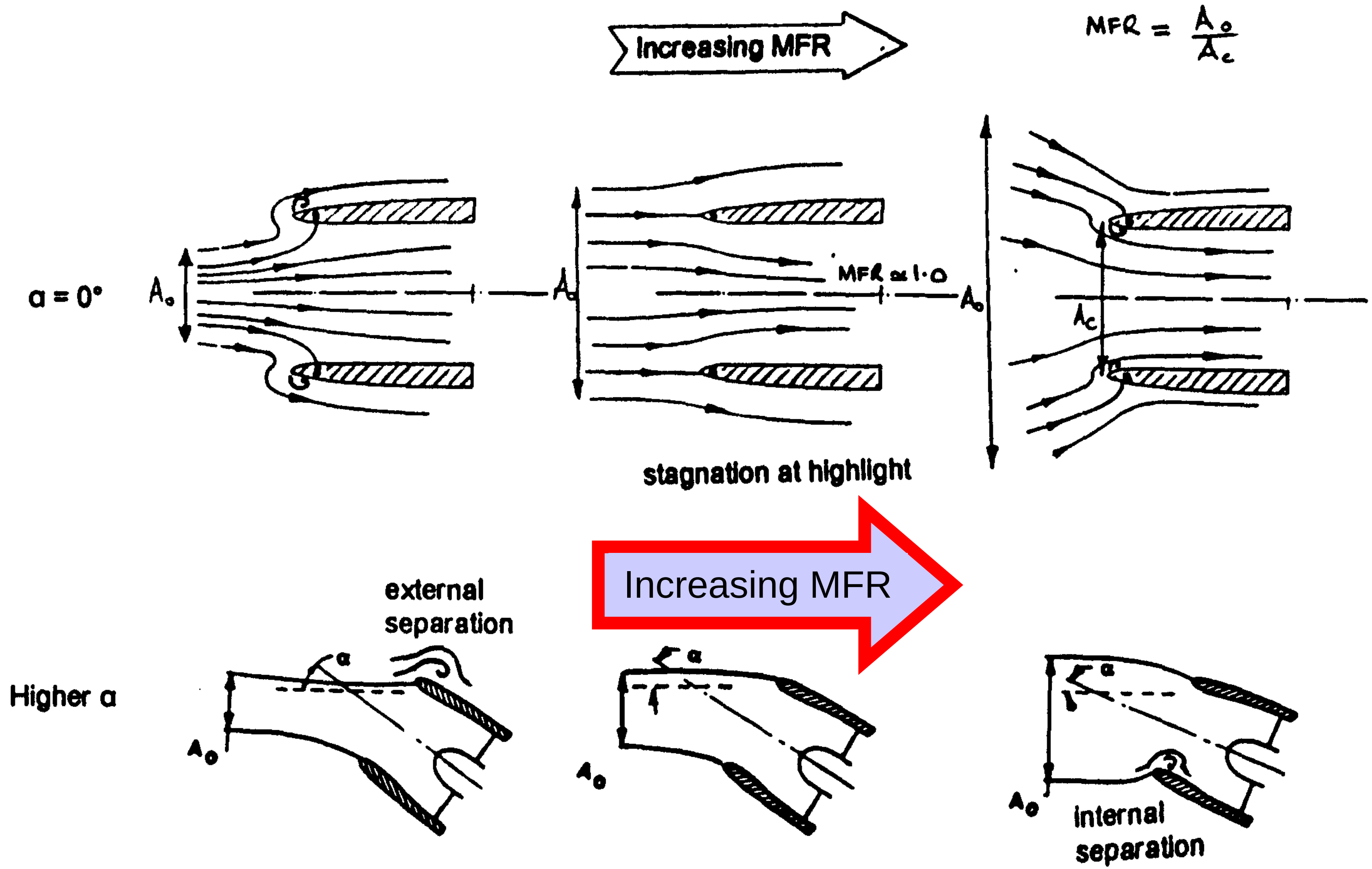




Central Fuselage intake

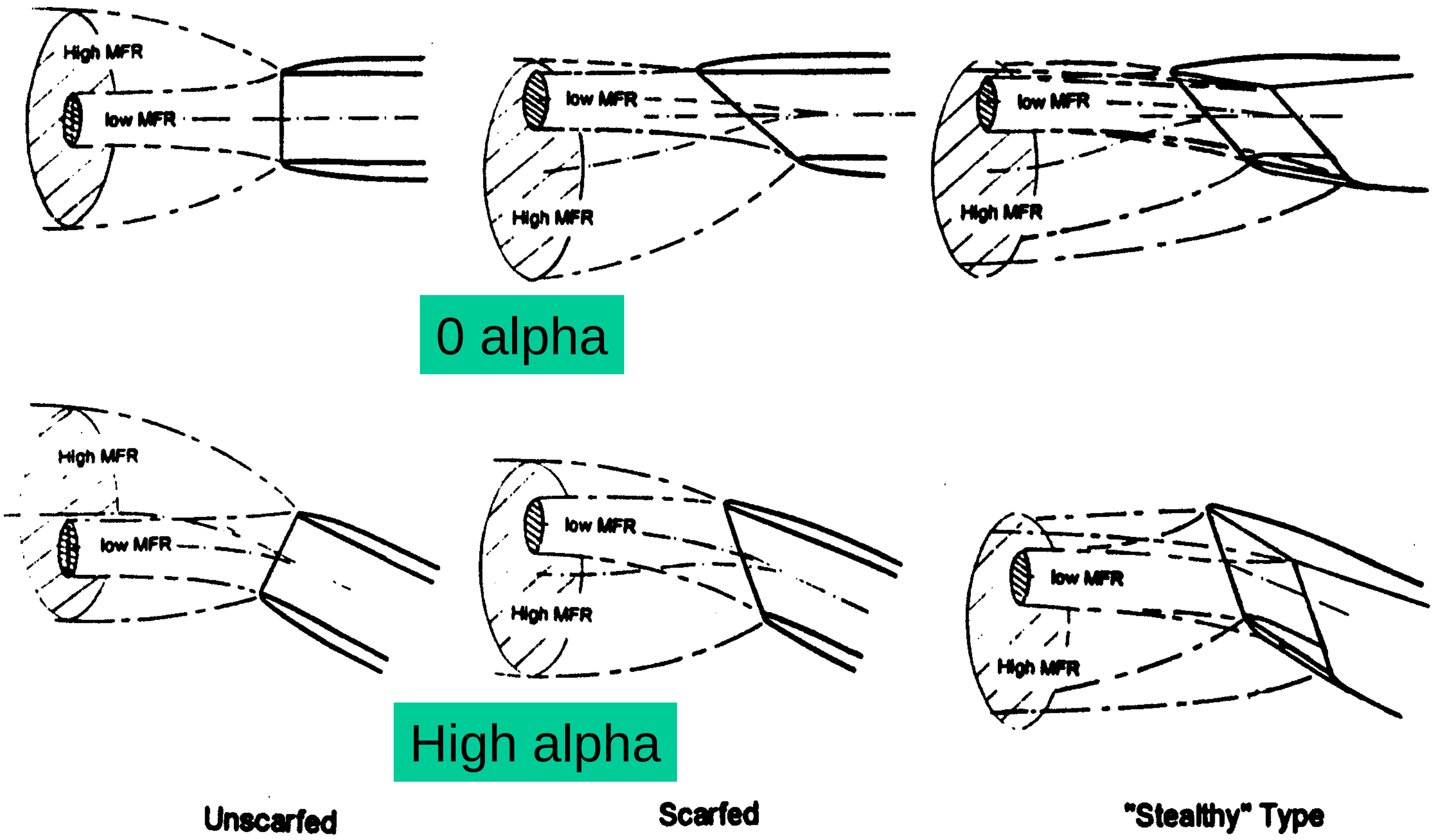


ORDER OF COMPLEXITY

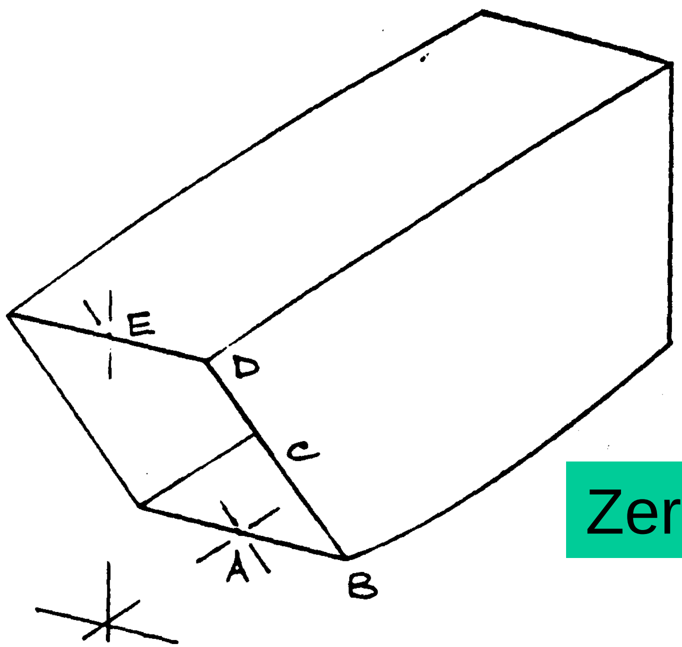


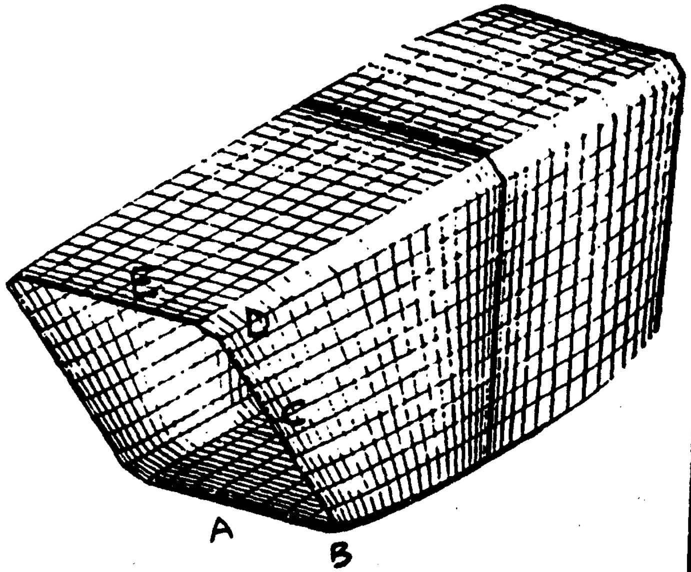
EFFECT OF MFR & a , ONSET OF EXTERNAL & INTERNAL LIP SEPARATION

UNSCARFED INTAKES

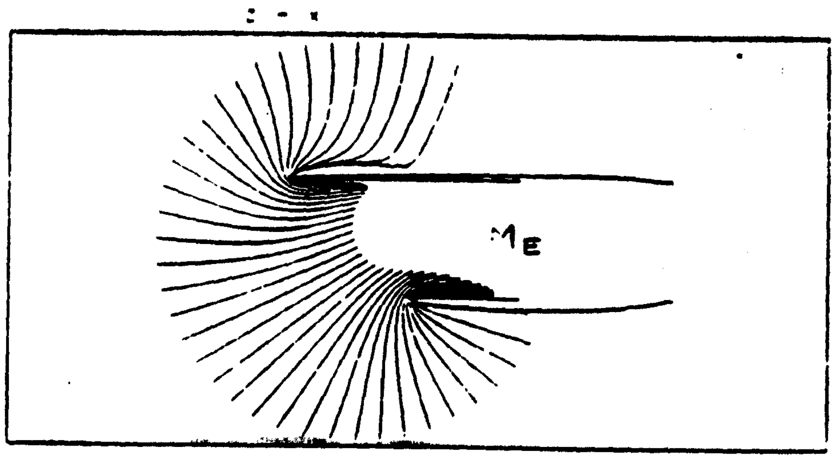


UNSCRAFED, SCARFED & 3-D STEALTHY INTAKES

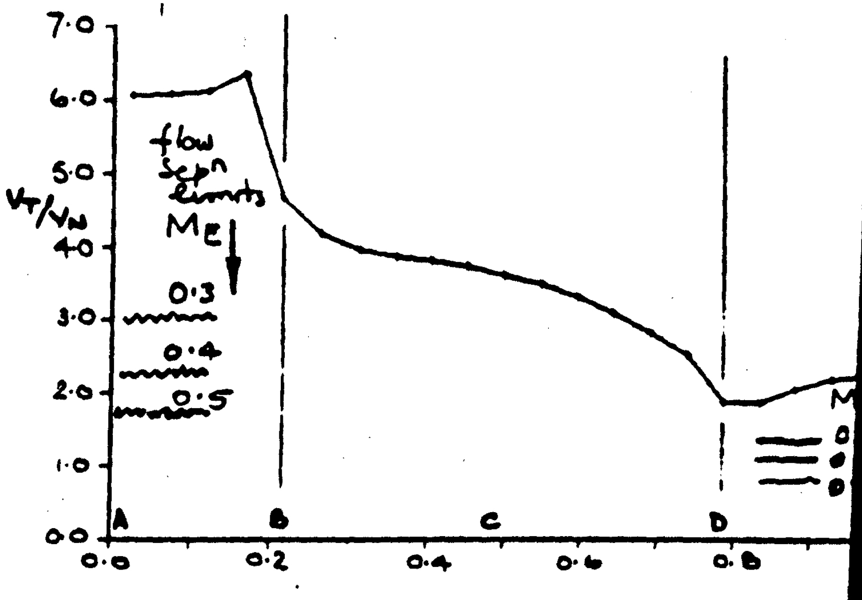




Zero speed

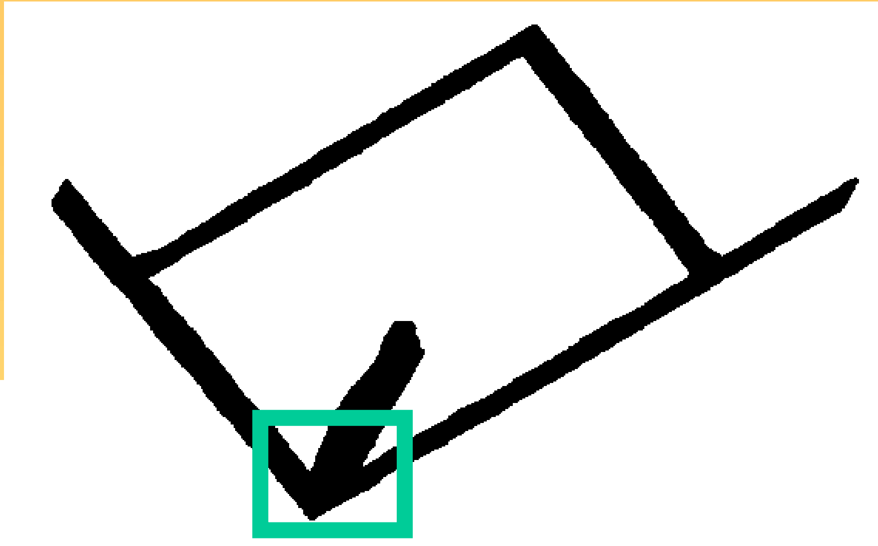


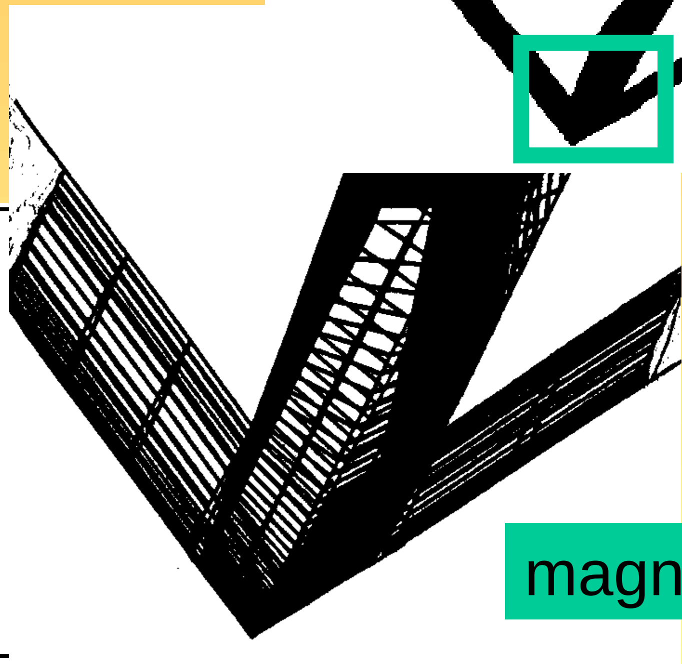
Streamlines, Symmetry plane



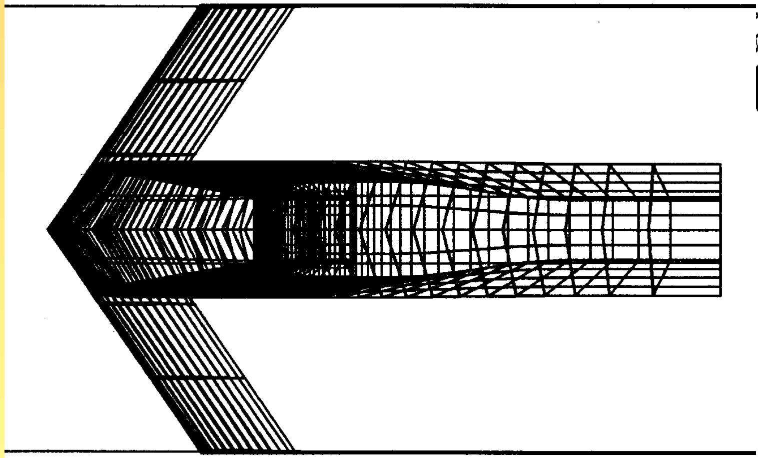
V_T along highlight perimeter & separation

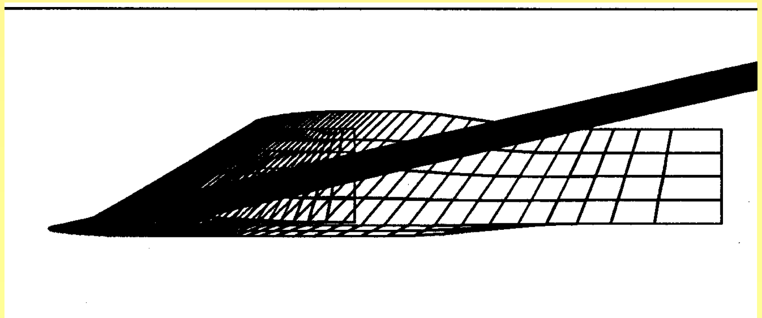
Central Intake Integration & Modelling

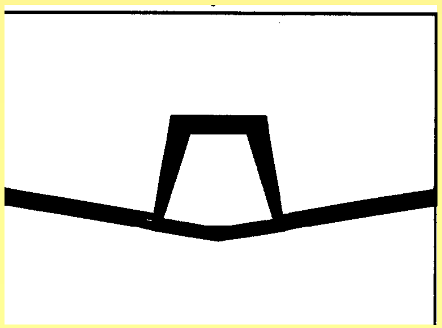


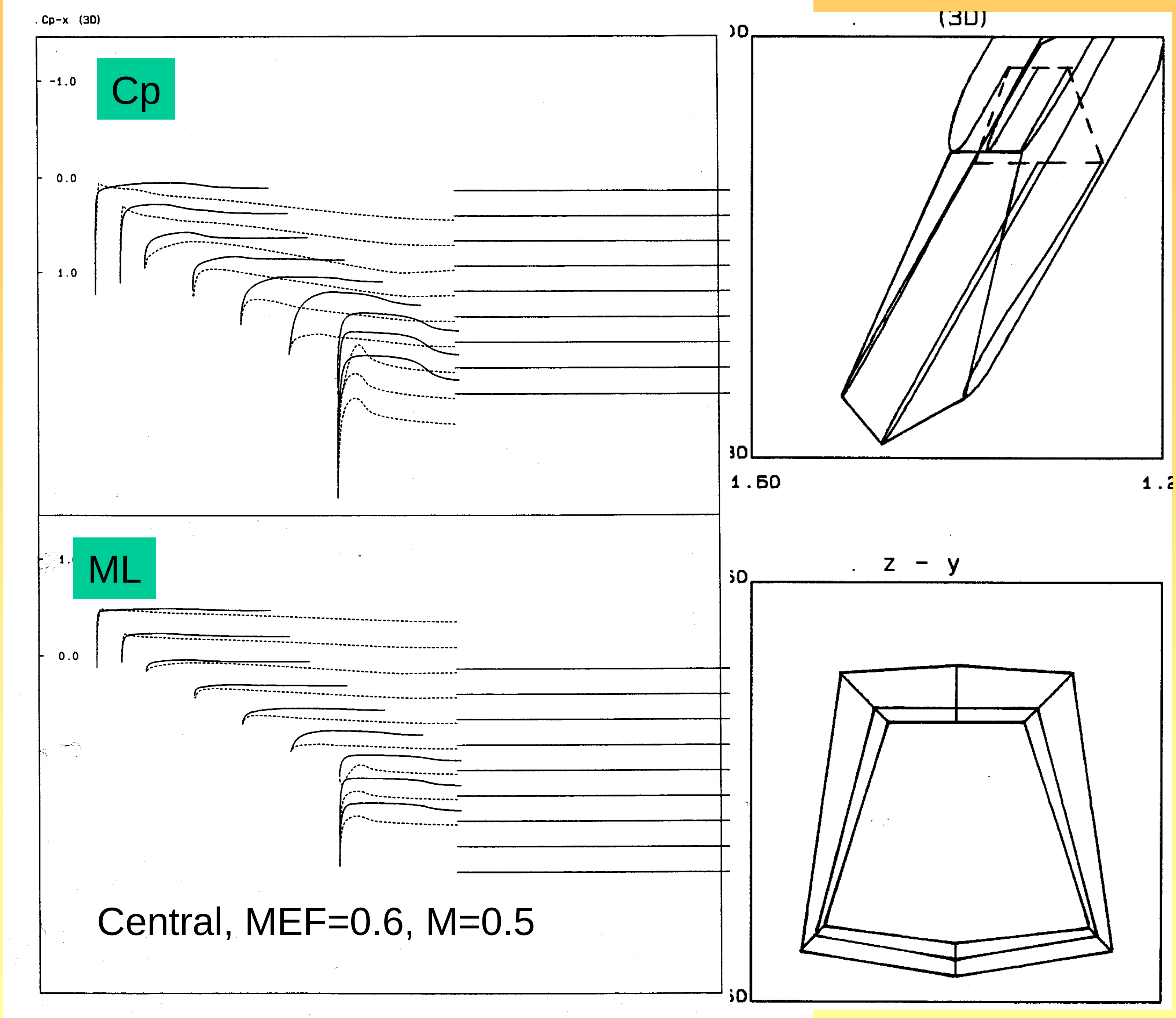


magnified

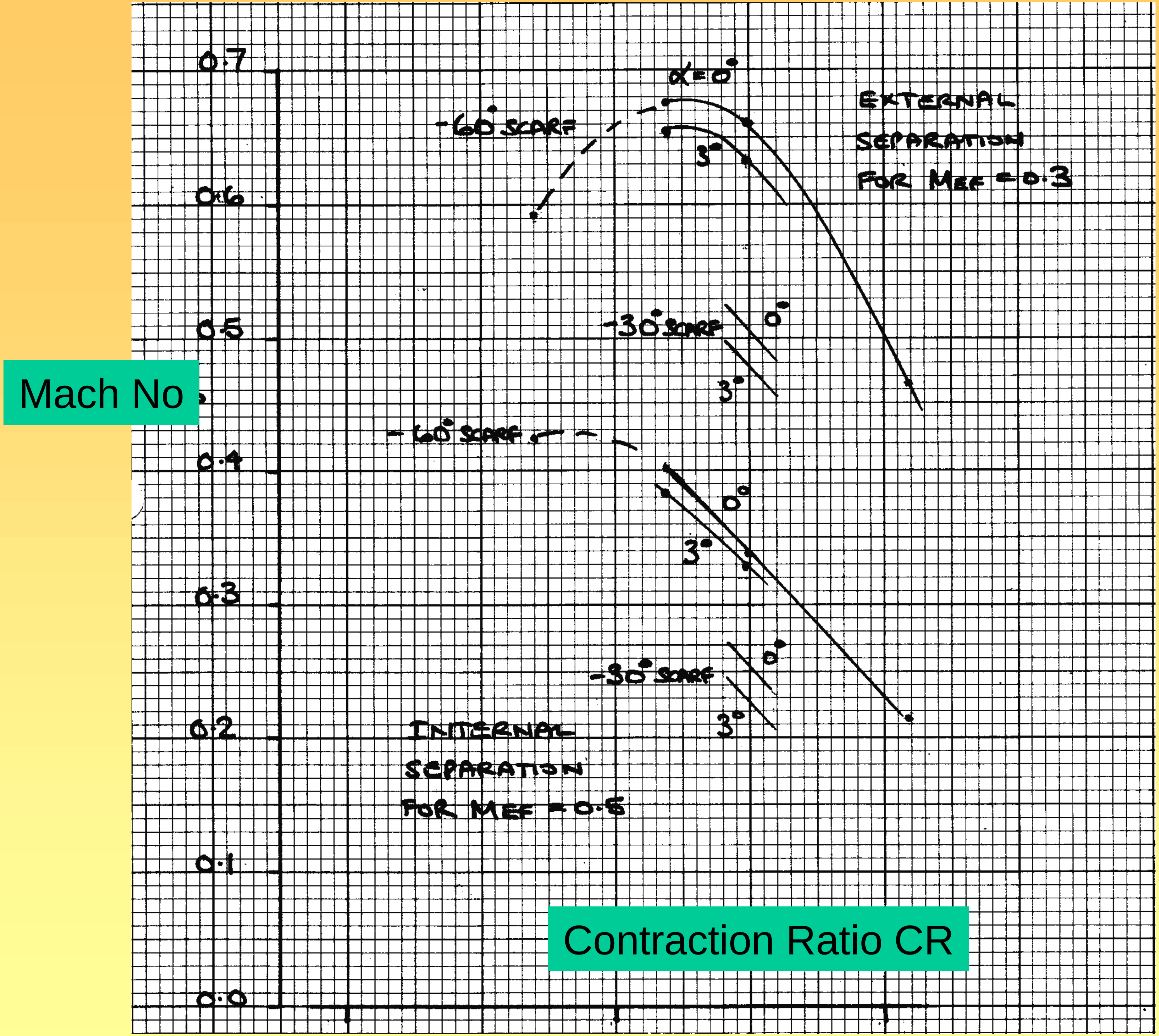








Central, MEF=0.6, M=0.5


Mach No
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
α = 0°
-60° SCARF
3°
EXTERNAL
SEPARATION
FOR MEF = 0.3
-30° SCARF
0°
3°
-60° SCARF
0°
3°
-30° SCARF
0°
3°
INTERNAL
SEPARATION
FOR MEF = 0.5
Contraction Ratio CR

Intakes, Propulsion

- Shown a Preliminary set of Results
- Sizing is the first Concern
- Altitude of Operation !
- Off-Design
- Suitable Power-plants !
- Possibly Two needed
- Work Continues ……
- Experimental Work needed

Configuration & Structure

- Configuration / Layout
- What Light Materials
- One or two Fuselage
- Are such high AR craft feasible, structure
- Aero-elastic tailoring
- Manufacturing Constraints

Aerodynamics / Flow Control / Control

- Viscous Effects: Laminar Flow Extent
- Spanwise press. gradients
- Effect of Sweep, lower sweep Config. !
- Field performance
- Off-design, side-slip
- Controls location, pitch, directional & lateral
- Off-design
- Flow control, what & where!

Experimental work

- Difficulty in modelling large AR Configs
- Reynolds Number Considerations
- Laminar flow in WT !
- Half models
- Control effects not representative of full-scale
- A Radio Control Free-Flight Model !
- Propulsion Integration Considerations

Concluding Remarks

- Introduced HALE - UAV
- A Vision of Future – Sensor Craft Importance
- Joined-Wing Configs.
- 2-D Laminar Aerofoils
- Different Type of Swept-Tips in 3-D
- Aspects of 3-D Design
- LE Suction Control, Elliptic loadings, Neutral Stab.
- CFD Checks – Forward-Swept Root area
- Inverse Design Capabilities
- Intake Design – Preliminary Work
- Avenues for Further Work

***** Thank You for Listening *****

So I hope, enough has been shown to interest and inform you in the fast moving field of Sensor-Craft

PLENTY of Further Work!

****

Shall we try Comments and Questions?