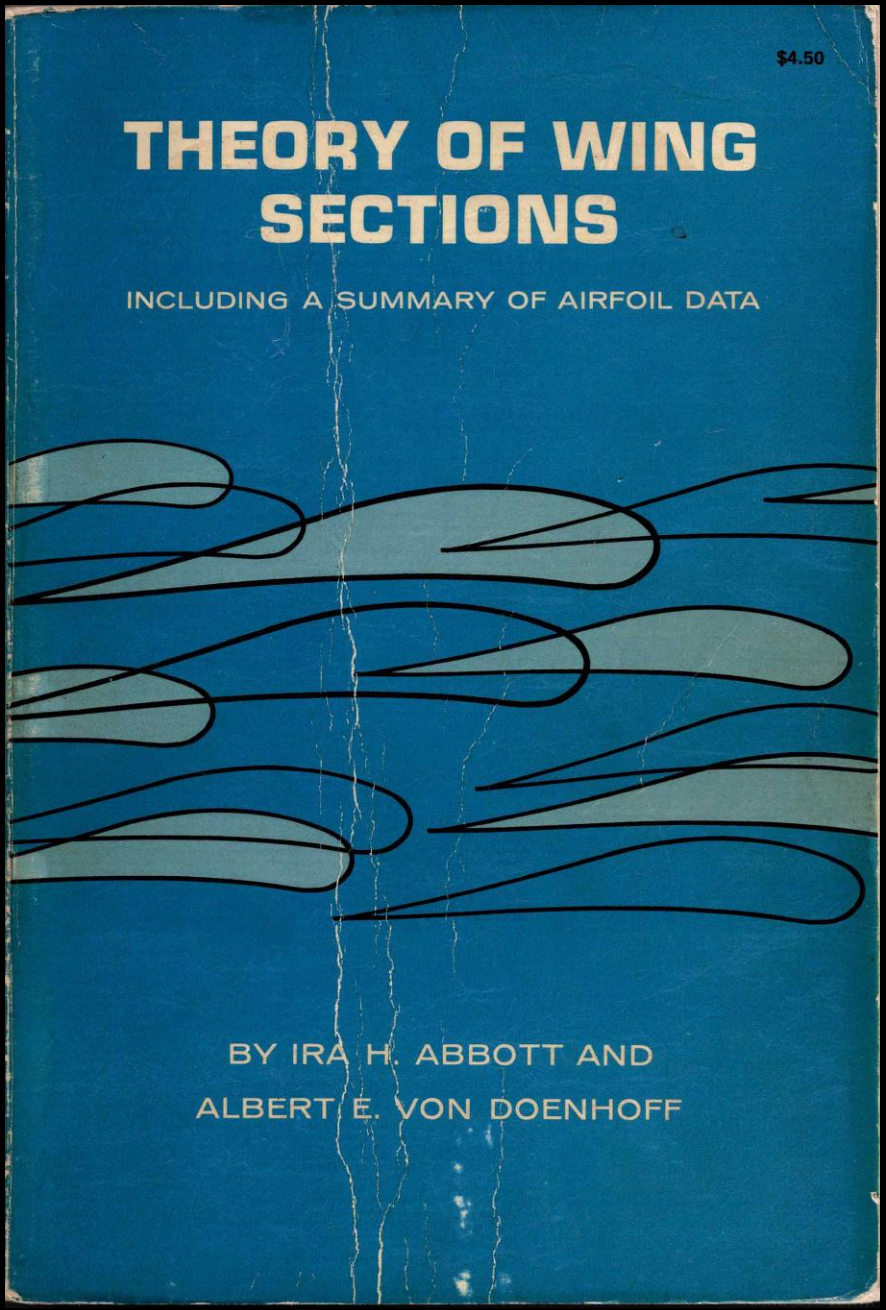
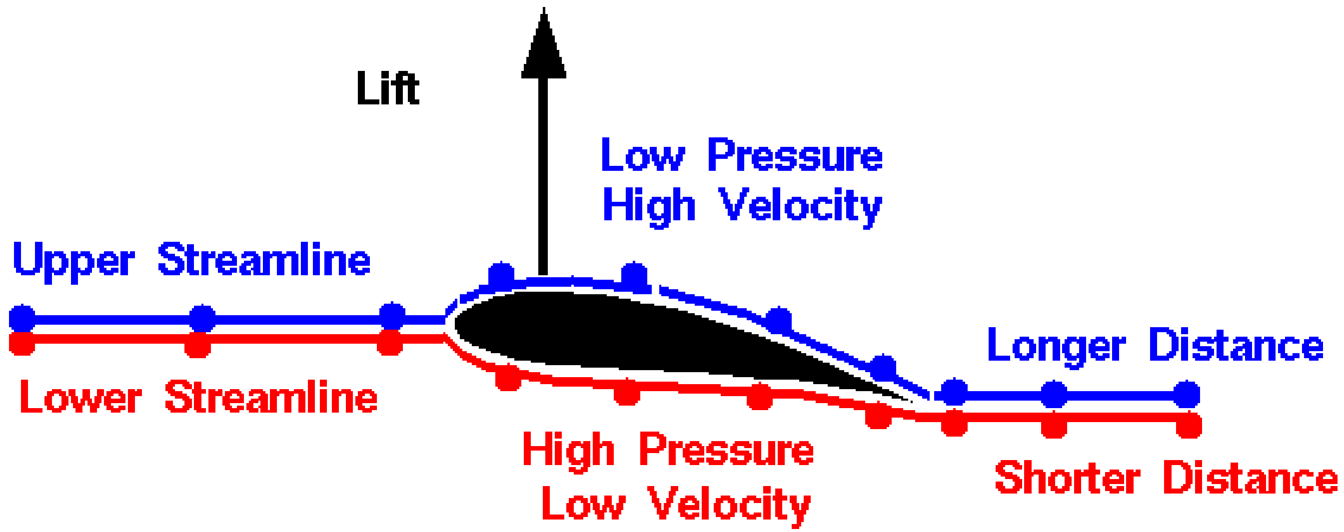


Maybe that title should reverse emphasis!

If any of you are young engineers, Note the price! When was the last time you bought an aero text for $4.50. It’s really thick too!

Incorrect Theory #1

Glenn Research Center



"Longer Path" or "Equal Transit" Theory

Top of airfoil is shaped to provide longer path than bottom.
Air molecules have farther to go over the top.

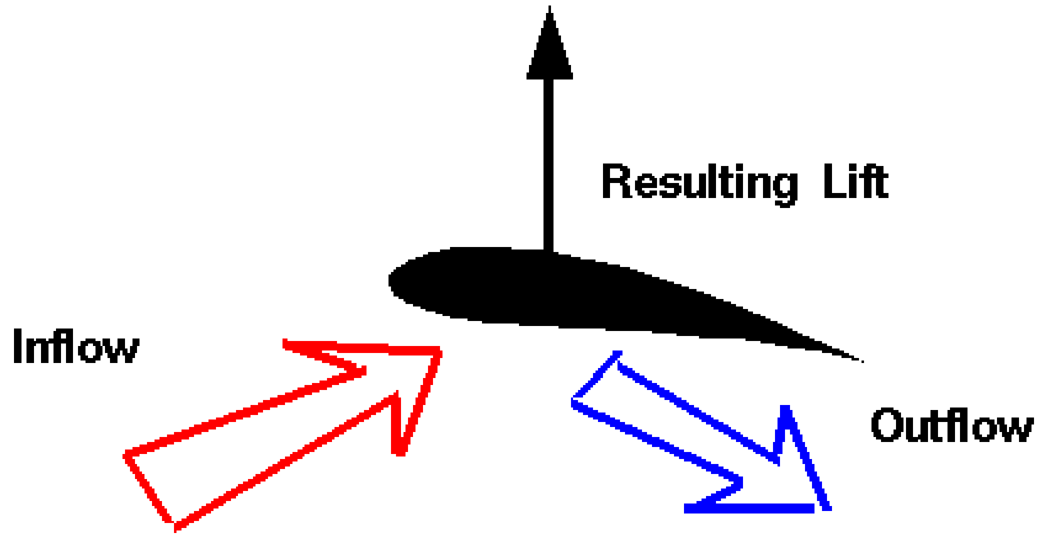
Air molecules must move faster over the top to meet molecules at the trailing edge that have gone underneath.

From Bernoulli's equation, higher velocity produces lower pressure on the top.

Difference in pressure produces lift.

Incorrect Theory #2

Glenn Research Center

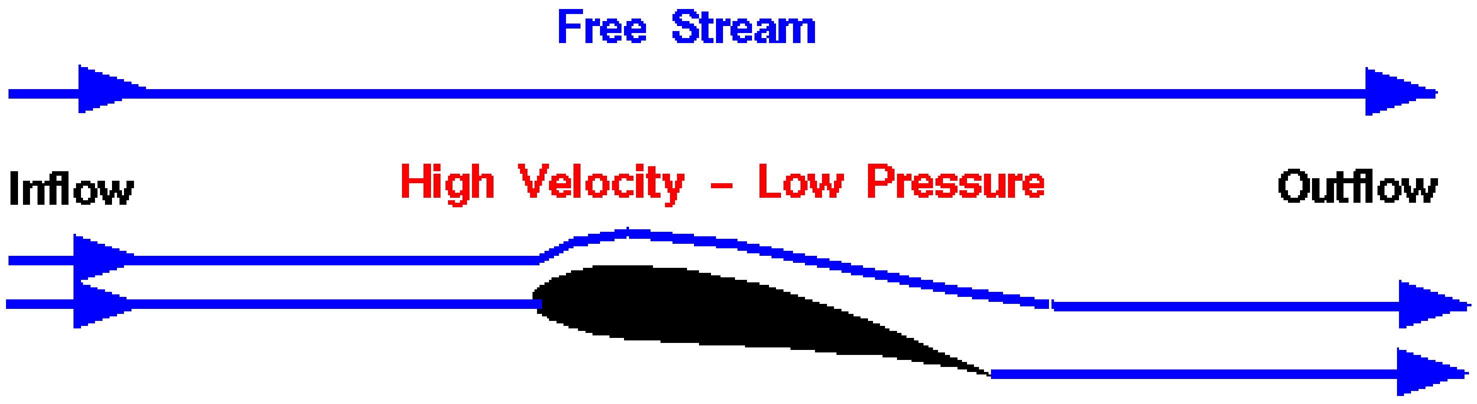


"Skipping Stone" Theory

Lift is the result of simple action <--> reaction as air molecules strike bottom of the airfoil imparting momentum to the foil.

Glenn Research Center

Incorrect Theory #3



"Venturi" Theory

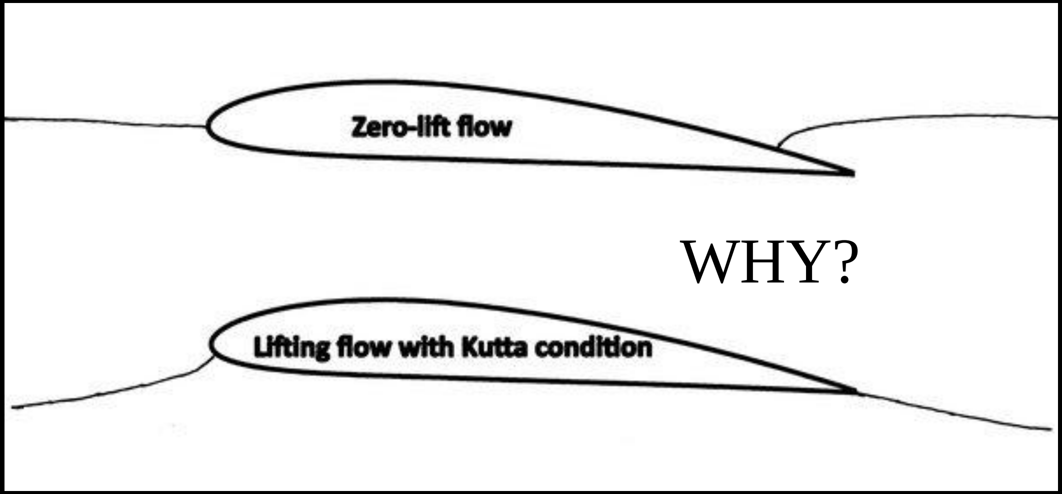
Upper surface of airfoil behaves like a Venturi nozzle constricting the flow.

Through the constriction, flow speeds up (velocity times area equals a constant).

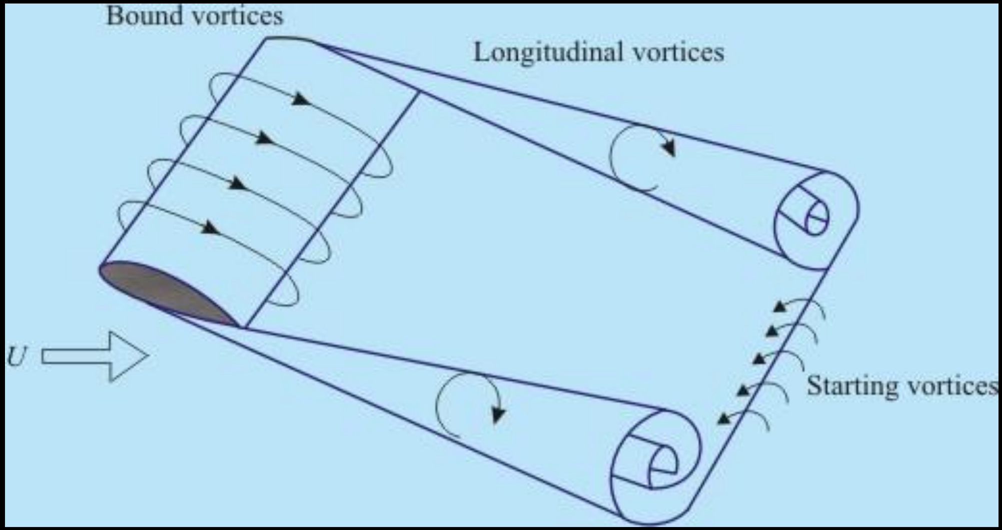
From Bernoulli's equation, high velocity gives low pressure.

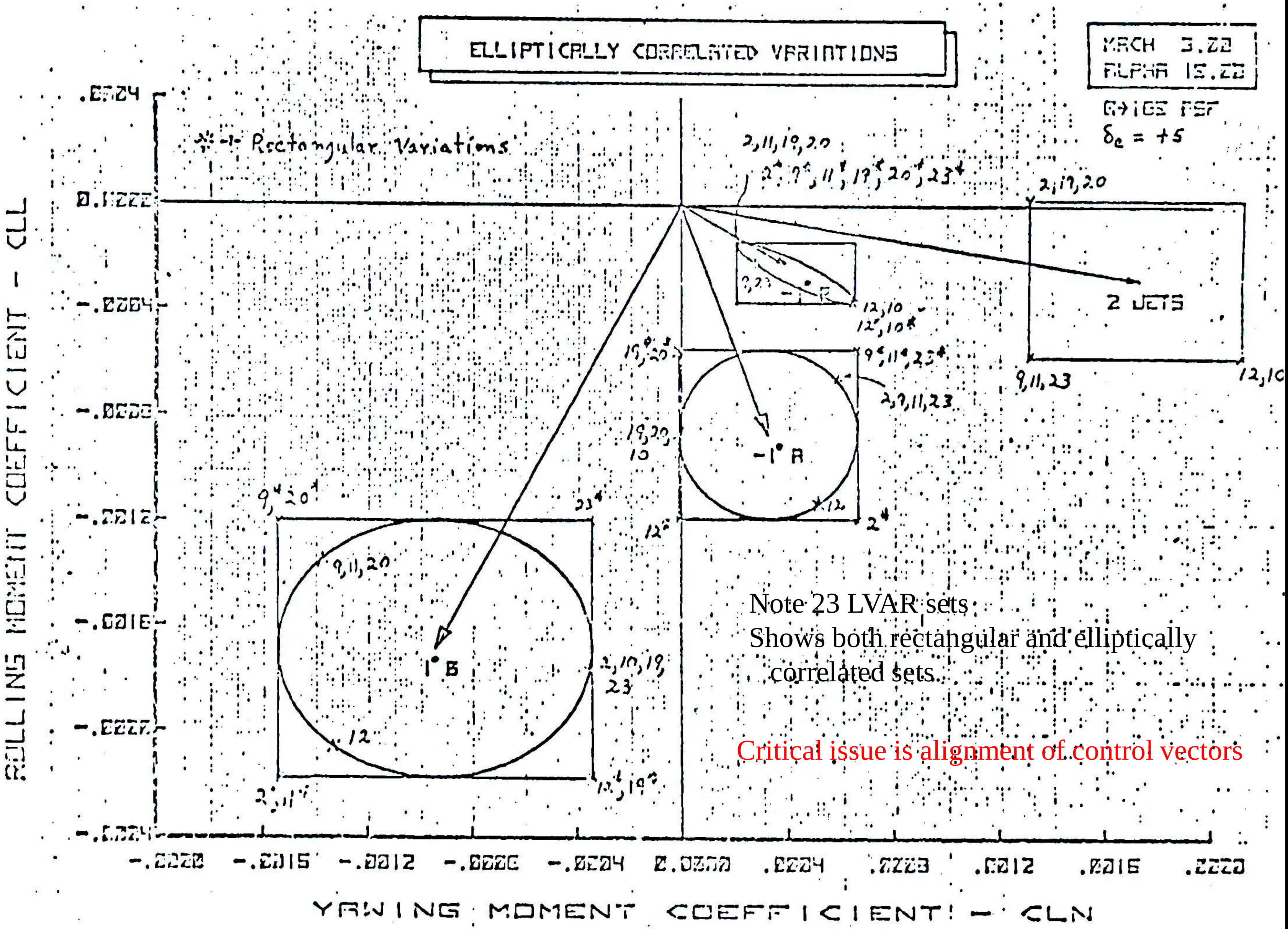
Decreased pressure on upper surface produces lift.

Kutta/Joukowski Theorum



Also wrong, but it is the least wrongest





Note 23 LVAR sets
Shows both rectangular and elliptically correlated sets.

Critical issue is alignment of control vectors

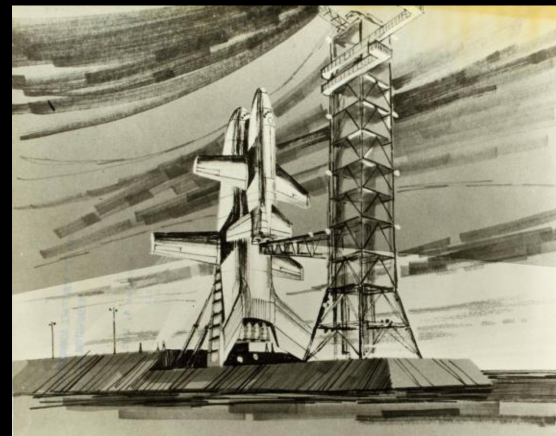
Throughout the process we fail and, consequently, repeatedly discover or learn that we have exceeded our understanding of the problem by moving beyond the bounds of our prior assumptions.

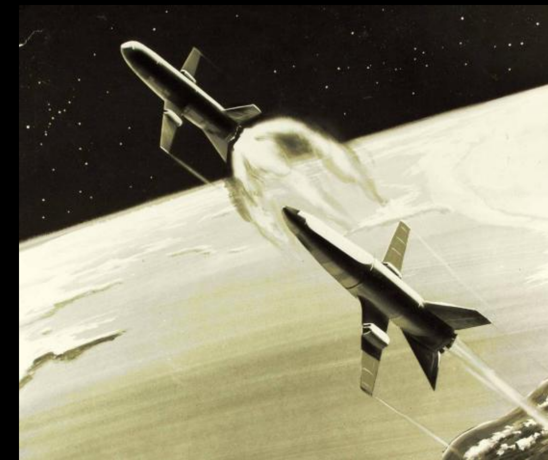
Dr. Charles J. Camarda

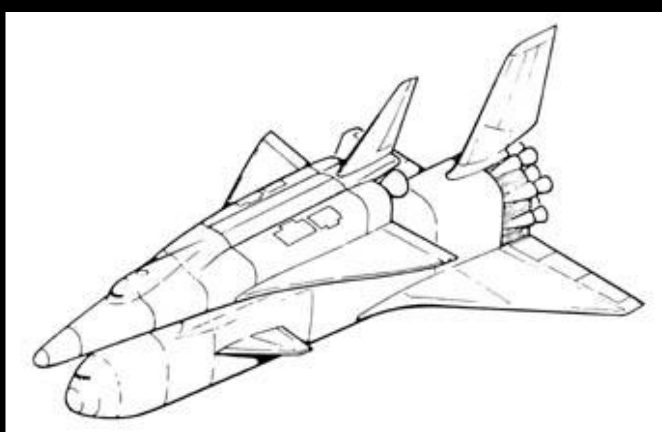
Strings of successes can mask insidious failures that our simple models of behavior cannot predict. Success combined with a "can do" spirit can lead to arrogance. This can perpetuate an "overconfidence bias" or confirmation bias, resulting in the subjective interpretation of data to confirm what we want to be true rather than what is actually true.

Dr. Charles J. Camarda

Straight wing

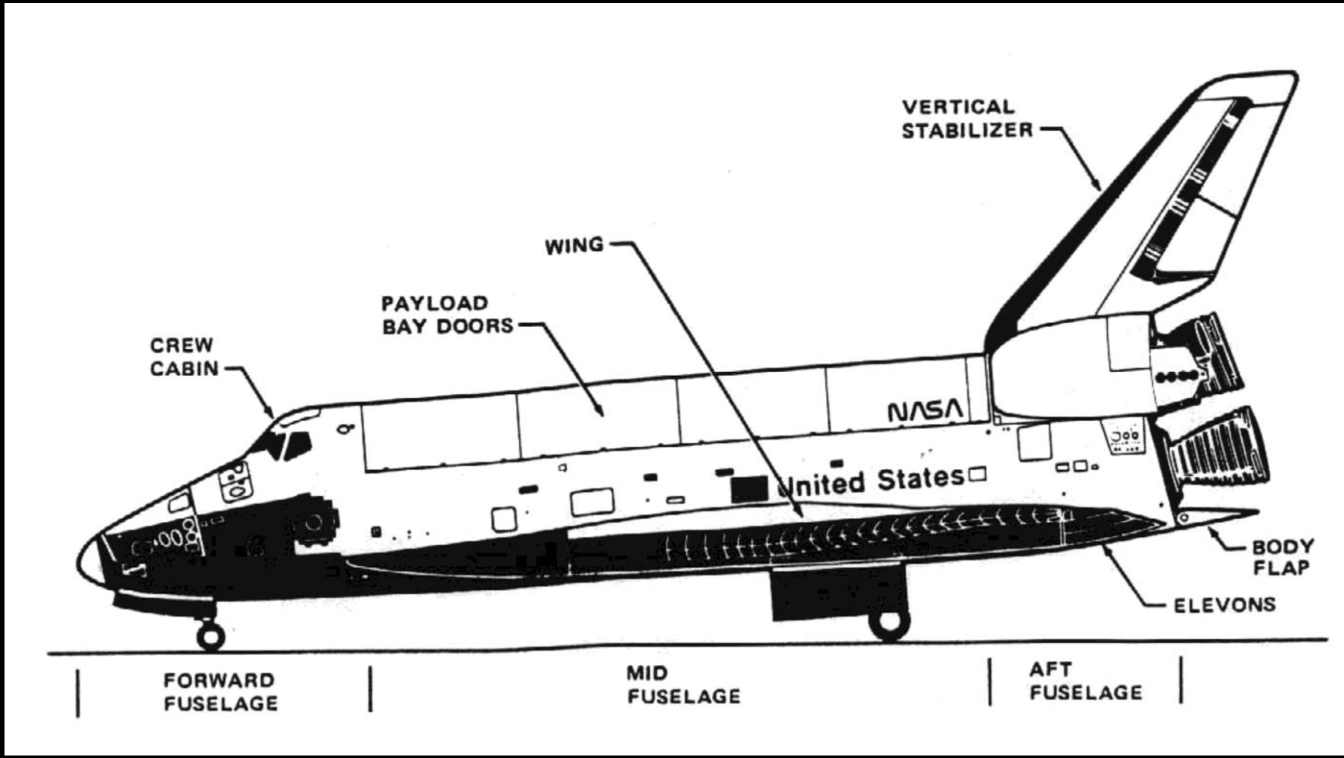






Delta – Fully Reusable

Partially Reusable
USAF preferred



Design changed during fabrication because of wind tunnel testing

- Shorten fuselage because of divergent nose up pitching moment
- Body flap/ Heat shield
- Nose landing gear shortened, main gear already made. (-5 degree α on roll out). Aero download almost same as vehicle weight! Brakes – tires.

Note approximately 5 degrees negative angle of attack on the ground during high speed rollout. Nearly doubles the landing gear and tire loads.

Vertical Tail blanked at 40 deg. AOA

$$\delta_{a\,trim} = \frac{C_{l\beta}\left(C_A \frac{\Delta Y}{b} - C_{n0}\right) + C_{n\beta}\left(C_N \frac{\Delta Y}{b} + C_{l0}\right)}{C_{l\beta} C_{n\delta_a} - C_{n\beta} C_{l\delta_a}}$$

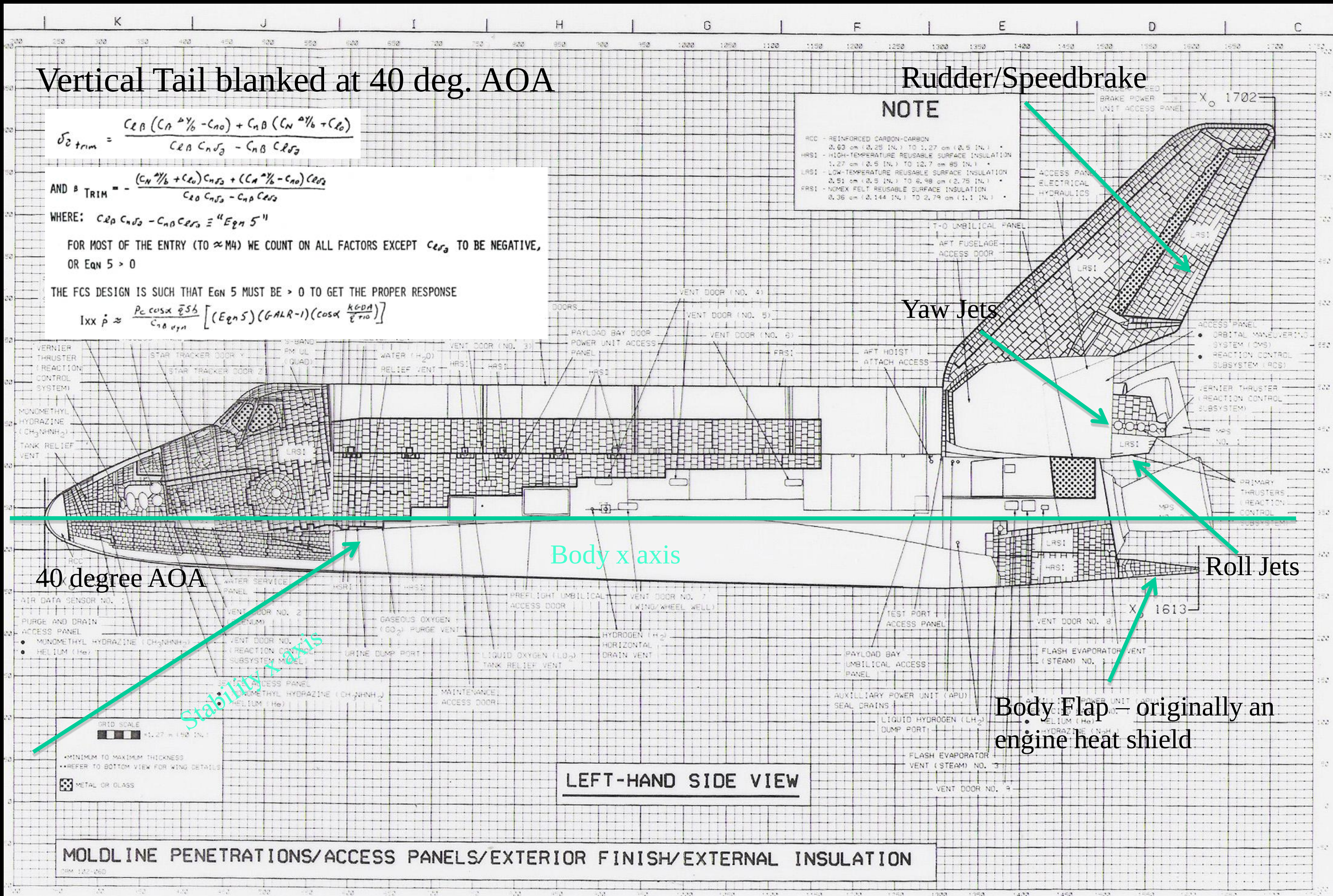
AND $\beta_{TRIM} = -\dfrac{\left(C_N \frac{\Delta Y}{b} + C_{l0}\right) C_{n\delta_a} + \left(C_A \frac{\Delta Y}{b} - C_{n0}\right) C_{l\delta_a}}{C_{l\beta} C_{n\delta_a} - C_{n\beta} C_{l\delta_a}}$

WHERE: $C_{l\beta} C_{n\delta_a} - C_{n\beta} C_{l\delta_a} \equiv$ "Eqn 5"

FOR MOST OF THE ENTRY (TO $\approx$ M4) WE COUNT ON ALL FACTORS EXCEPT $C_{l\delta_a}$ TO BE NEGATIVE, OR EQN 5 > 0

THE FCS DESIGN IS SUCH THAT EGN 5 MUST BE > 0 TO GET THE PROPER RESPONSE

$$I_{xx}\,\dot{p} \approx \frac{P_c \cos\alpha\, \bar{q} S b}{C_{n\beta\,dyn}} \left[(Eqn\,5)(GALR-1)\left(\cos\alpha\, \frac{KGDA}{\bar{q}\,r_{10}}\right) \right]$$



DIVIDING THE MOMENT EQUATIONS BY $\bar{q}\,sb$ AND THE FORCE EQUATION BY $\bar{q}\,s$ YIELDS

$$C_n = C_{n\beta}\,\beta + C_{n\delta_a}\,\delta_a + C_{n\delta_r}\,\delta_r - \left(C_A \frac{\Delta Y}{b} - C_{n_0}\right) = 0$$

$$C_\ell = C_{\ell\beta}\,\beta + C_{\ell\delta_a}\,\delta_a + C_{\ell\delta_r}\,\delta_r + \left(C_N \frac{\Delta Y}{b} + C_{\ell_0}\right) = 0$$

$$C_Y = C_{Y\beta}\,\beta + C_{Y\delta_a}\,\delta_a + C_{Y\delta_r}\,\delta_r = 0$$

$$\begin{vmatrix} C_{n\beta} & C_{n\delta_a} & C_{n\delta_r} \\ C_{\ell\beta} & C_{\ell\delta_a} & C_{\ell\delta_r} \\ C_{Y\beta} & C_{Y\delta_a} & C_{Y\delta_r} \end{vmatrix} \begin{vmatrix} \beta \\ \delta_a \\ \delta_r \end{vmatrix} = \begin{vmatrix} C_A \frac{\Delta Y}{b} - C_{n_0} \\ -\left(C_N \frac{\Delta Y}{b} + C_{\ell_0}\right) \\ 0 \end{vmatrix}$$

IN THE "EARLY" SYSTEM RUDDER IS BLANKED BY THE WING AND IS NOT USED; SO $\delta_r \equiv 0$ AND THE EQUATIONS BECOME

$$\begin{vmatrix} C_{n\beta} & C_{n\delta_a} \\ C_{\ell\beta} & C_{\ell\delta_a} \end{vmatrix} \begin{vmatrix} \beta \\ \delta_a \end{vmatrix} = \begin{vmatrix} C_A \frac{\Delta Y}{b} - C_{n_0} \\ -\left(C_N \frac{\Delta Y}{b} + C_{\ell_0}\right) \end{vmatrix}$$

SOLVING FOR $\delta_{a\,trim}$ and β_{trim} BY CRAMERS RULE GIVES

$$\delta_{a\,trim} = \frac{C_{\ell\beta}\left(C_A \Delta Y/b - C_{n_0}\right) + C_{n\beta}\left(C_N \Delta Y/b + C_{\ell_0}\right)}{C_{\ell\beta}\,C_{n\delta_a} - C_{n\beta}\,C_{\ell\delta_a}}$$

AND $\beta_{TRIM} = -\dfrac{(C_N \Delta Y/b + C_{\ell_0}) C_{n\delta_a} + (C_A \Delta Y/b - C_{n0}) C_{\ell\delta_a}}{C_{\ell\beta} C_{n\delta_a} - C_{n\beta} C_{\ell\delta_a}}$

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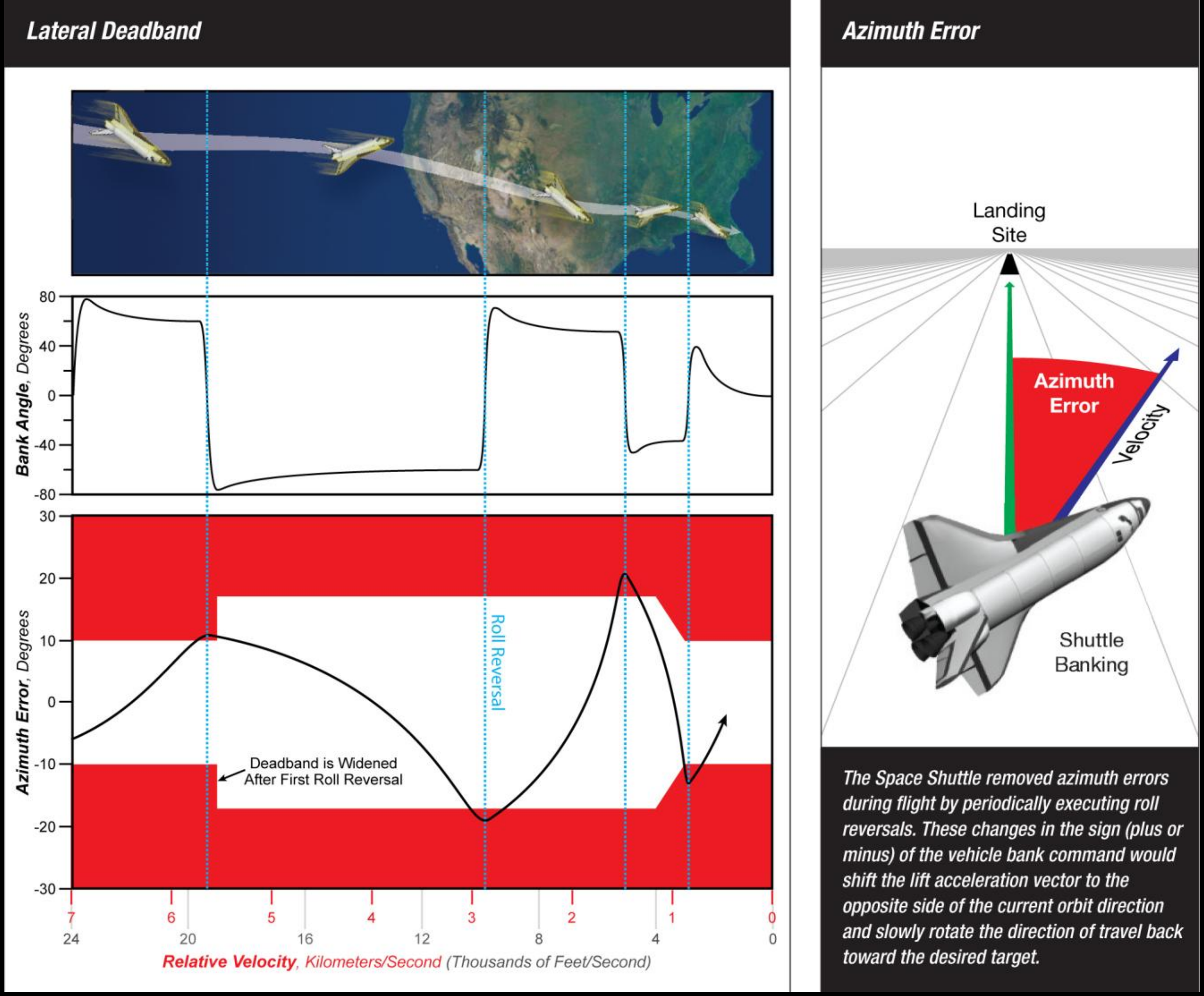
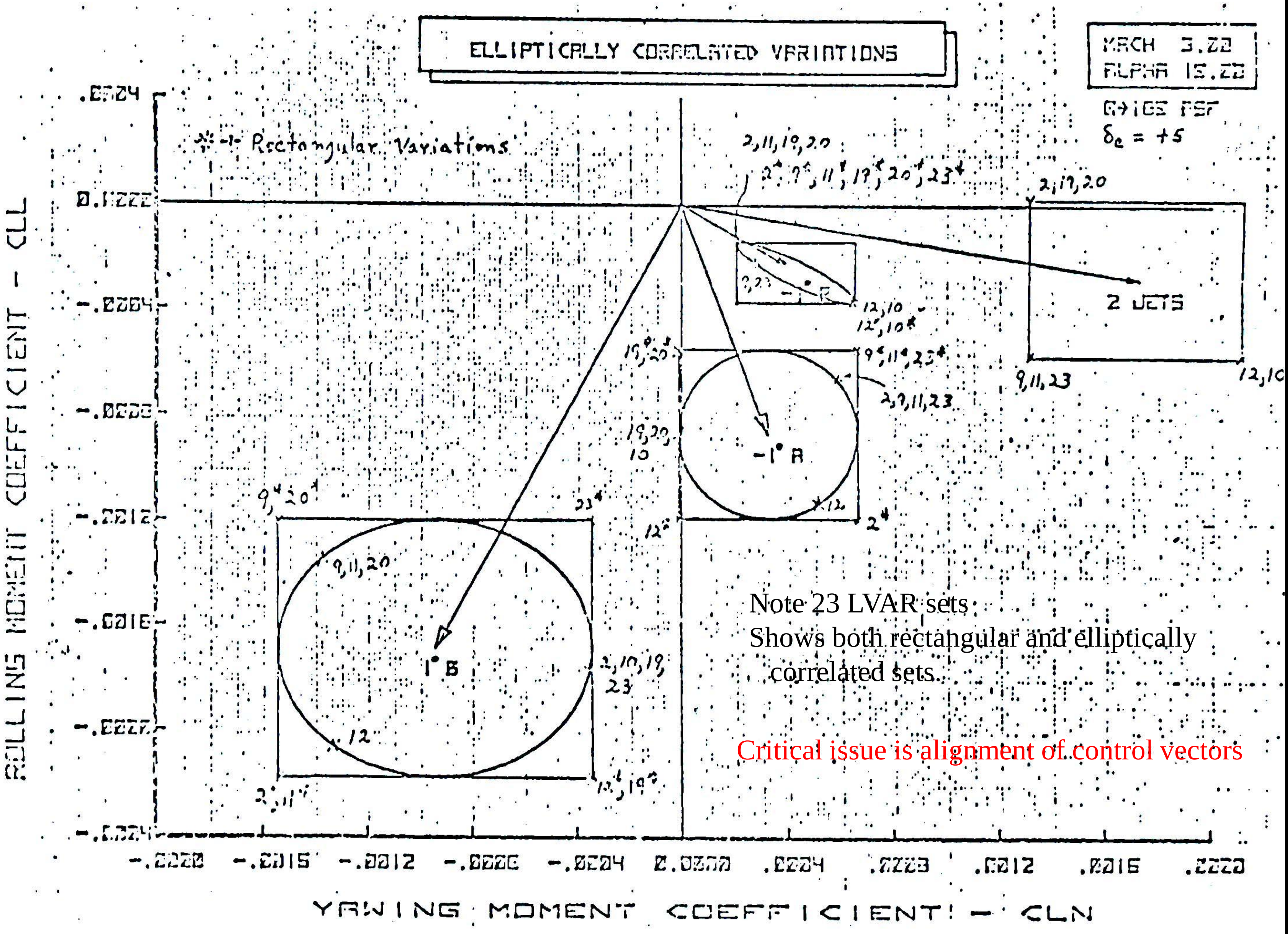
DURING EARLY ENTRY GALR = 1.1 SO FAR A PROPER ROLL ACCELERATION, $\dot{p}$, IN RESPONSE TO ROLL COMMAND p_c, EGN 5 MUST BE > 0.

THE TERM $C_{n\beta\,dyn} = C_{n\beta}\cos\alpha - C_{\ell\beta}\sin\alpha\,\frac{I_{zz}}{I_{xx}}$ IS ORBITER DIRECTIONAL STABILITY DRIVER. THUS THE CRITERIA FOR STABLE $C_{n\beta\,dyn}$ IS:

$$\overset{(-)}{C_{n\beta}}\ \overset{(+)}{\cos\alpha} - \overset{(-)}{C_{\ell\beta}}\ \overset{(+)}{\sin\alpha}\ \overset{(+)}{\frac{I_{zz}}{I_{xx}}} > 0 \implies \frac{C_{n\beta}}{C_{\ell\beta}} < \tan\alpha\ \frac{I_{zz}}{I_{xx}}$$



Guidance computes range to go and determines how much drag we need on the vehicle to get to the runway. S-turning across the ground track allows us to control drag without letting cross range distance diverge



Note 23 LVAR sets
Shows both rectangular and elliptically correlated sets.

Critical issue is alignment of control vectors

AND $\beta_{TRIM} = - \dfrac{(C_N \Delta Y/b + C_{\ell_0}) C_{n_{\delta_a}} + (C_A \Delta Y/b - C_{n_0}) C_{\ell_{\delta_a}}}{C_{\ell_\beta} C_{n_{\delta_a}} - C_{n_\beta} C_{\ell_{\delta_a}}}$

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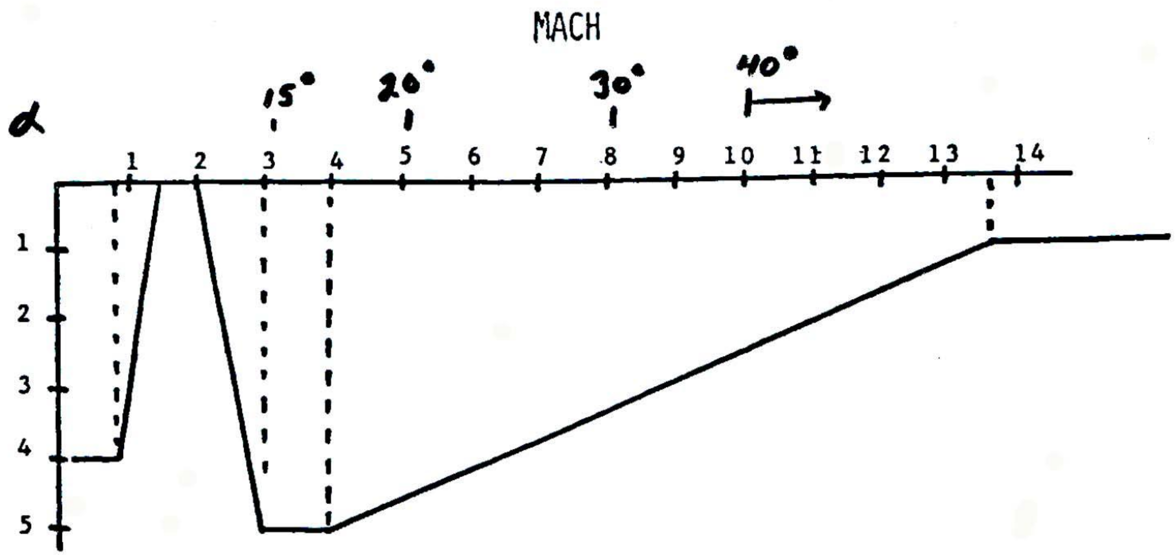

ELEVON SCHEDULE

M > 13.6 - HEATING CONSTRAINT

M 13.6 TO M 3 - ELEVON DRIVEN DOWN (AT A SCHEDULE WHICH CAN BE TRIMMED BY THE BODY FLAP) TO MAINTAIN NEGATIVE $c_{n\delta a}$ FOR YAW TRIM WITH AILERONS.

M 3 TO M 2 - ELEVON GOES UP SO THAN $c_{n\delta a}$ DOES NOT FIGHT THE RUDDER FOR YAW TRIM. ALSO C_m CHANGE REQUIRES IT FOR PITCH TRIM.

M 1.5 TO M 0.9 - ELEVON DRIVEN DOWN ALONG A NEAR ZERO HINGE MOMENT PROFILE TO AVOID POSSIBLE SURFACE RATE SATURATION.

STS-1 launched
April 12, 1981

U.S. Government
MEMORANDUM
Lyndon B. Johnson Space Center NASA

REFER TO: CB	DATE October 16, 1979	INITIATOR CB/RLStewart:mg:10/16/79:3856	ENCL

TO: Distribution

CC: Autotaxing see?

FROM: CB/R. L. Stewart

SIGNATURE Bob Stewart
Robert L. Stewart

SUBJ: FSL Verification Status Overview

1. Entry verification was halted the first week in October to investigate previously observed anomalies. The conclusion drawn was that the FCS tolorance sets designed by Honeywell were much to severe and amounted to a 9σ FCS. Tolerances were added worst on worst rather than taking an RSS value. Many of the anomalies observed during verification may be attributed to this grossly degraded LRU and actuator error model. As presently formulated the FCS is not suitable for flight, but no redesign will be undertaken until Honeywell can compile and Rockwell test a legitimate 3σ FCS. As an interim measure RI resumed handling qualities tests on October 8 with two new trial tolerance sets; one combined the old "3σ" LRU's with "1σ" actuators, and the other combined "1σ" LRU's with "3σ" actuators. The actual error involved probably fell somewhere less than 9σ but greater than 3σ. This change was not noticable in the cockpit. Qualitatively no difference could be seen between the two tolerance sets and system performance was not noticably improved.

2. Handling qualities tests conducted through Wednesday Oct 10 produced no surprises. The sim went down on Oct 10, due to a failure of a D to A converter, and remained down Thursday and Friday.

3. On Monday Oct 15, I briefed Warren North and Ken Cox on my assessment of the current verification status. Other attendees were Milt Contella, Ernie Smith, Jon Harpold, Joe Gamble, and Ox van Hoften. The remainder of this memo will present the points discussed during this briefing. Issues generally fell into two categories: conduct of the simulation, and FCS problems as tested. The bottom line conclusion was that we are not making progress in verifying an entry FCS for STS-1 because several problems not shown on previous math model development sims make the "as tested" FCS unsuitable for flight. I feel that we should be investigating these problems rather than "filling in the squares" with completed verification runs. We are writing a bunch of TDR's on the test but you can't fly TDR's; they don't even make good SRB fuel.

4. The major difference noticed in performance of the E5 DAP as formulated by IBM and as designed on math model sims is the degraded roll damping. This degradation is evident in the larger values of roll angle overshoot with nominal FCS and unacceptably large roll angle overshoots with the present FCS tolerances (9σ). This degraded roll damping causes outright loss of control with variation set 12, in either Auto or CSS mode, at approximately M2.4 to M2.0. But poor roll damping is also responsible for trajectory control problems with other lateral variation sets as

If there are any manager types here whom
I have not yet offended
Please invite me back, because that’s my
Job as an Experimental Test Pilot,
and I hate to leave a job unfinished!