Aircraft Design and Constraint Analysis for Carrier Operations

AMY DWYER FRANK O'BRIMSKI
CONCEPTUAL DESIGN DIVISION
NAVAIR SYSCOM

Dr. Dimitri N. Mavris, Director ASDL
School of Aerospace Engineering
Georgia Institute of Technology
Atlanta, GA 30332-0150
dimitri.mavris@ae.gatech.edu

PURPOSE

Provide an OVERVIEW of how operating on and around the carrier constrains the aircraft design.

Dr. Dimitri N. Mavris, Director ASDL
School of Aerospace Engineering
Georgia Institute of Technology
Atlanta, GA 30332-0150
dimitri.mavris@ae.gatech.edu

OPERATIONAL EFFECTIVENESS

Achieving Favorable Match-ups Against LAND-BASED Adversaries When Considering:

INDIVIDUAL AIRCRAFT

- RADIUS
- COMBAT AGILITY
- WEAPONRY
- SENSORS
- SURVIVABILITY

AND

AIRWING ATTRIBUTES

- NIGHT Ops
- ADVERSE WEATHER Ops
- SORTIE GENERATION
- RESPONSE TIMES
- NUMBER OF AIRCRAFT

AND BEING CARRIER SUITABLE

Dr. Dimitri N. Mavris, Director ASDL
School of Aerospace Engineering
Georgia Institute of Technology
Atlanta, GA 30332-0150
dimitri.mavris@ae.gatech.edu

ENHANCE SORTIE GENERATION RATE

CARRIER EQUIPMENT

- Multiple Catapults
- Multiple Elevators
- Jet Blast Deflectors
- Tractors & Dollies

AIRCRAFT DESIGN

- Geometric Compatibility With Carrier Equipment
- On Deck Maneuverability
- Nose Tow Launch With Autonomous Hook Up
- Fold & Unfold Under Own (Idle) Power
- Unassisted Cable Release / Hook Retraction

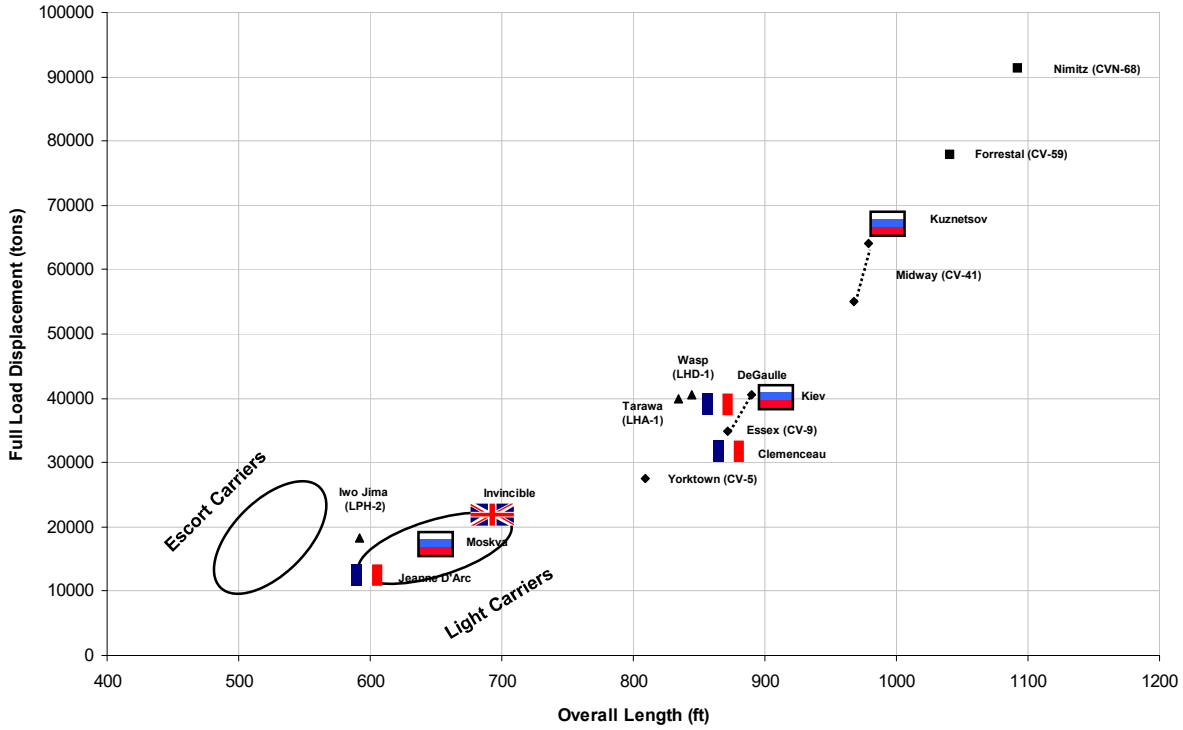
Dr. Dimitri N. Mavris, Director ASDL
School of Aerospace Engineering
Georgia Institute of Technology
Atlanta, GA 30332-0150
dimitri.mavris@ae.gatech.edu

OPERATING CONDITIONS

- SPACE COMPRESSION
  - Confined Area to Conduct Ops
  - Thermal and Acoustic Hazards
- MARITIME ENVIRONMENT
  - High Winds
  - Moving Deck
  - Moisture on Deck
- DENSE ELECTROMAGNETIC ENVIRONMENT

Dr. Dimitri N. Mavris, Director ASDL
School of Aerospace Engineering
Georgia Institute of Technology
Atlanta, GA 30332-0150
dimitri.mavris@ae.gatech.edu

AIRCRAFT CARRIER DESIGN TRENDS

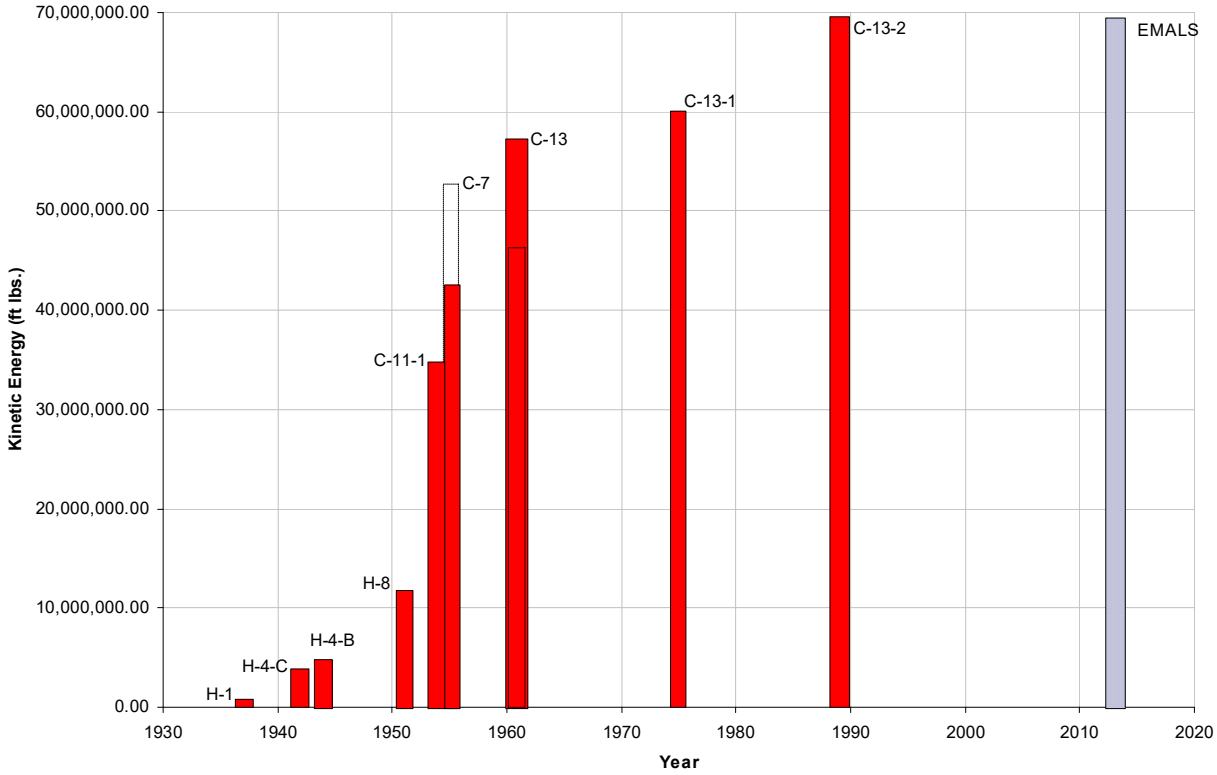


Dr. Dimitri N. Mavris, Director ASDL
School of Aerospace Engineering
Georgia Institute of Technology
Atlanta, GA 30332-0150
dimitri.mavris@ae.gatech.edu

AIRCRAFT LAUNCH AND RECOVERY EQUIPMENT

Dr. Dimitri N. Mavris, Director ASDL
School of Aerospace Engineering
Georgia Institute of Technology
Atlanta, GA 30332-0150
dimitri.mavris@ae.gatech.edu

CATAPULT PERFORMANCE



Dr. Dimitri N. Mavris, Director ASDL
School of Aerospace Engineering
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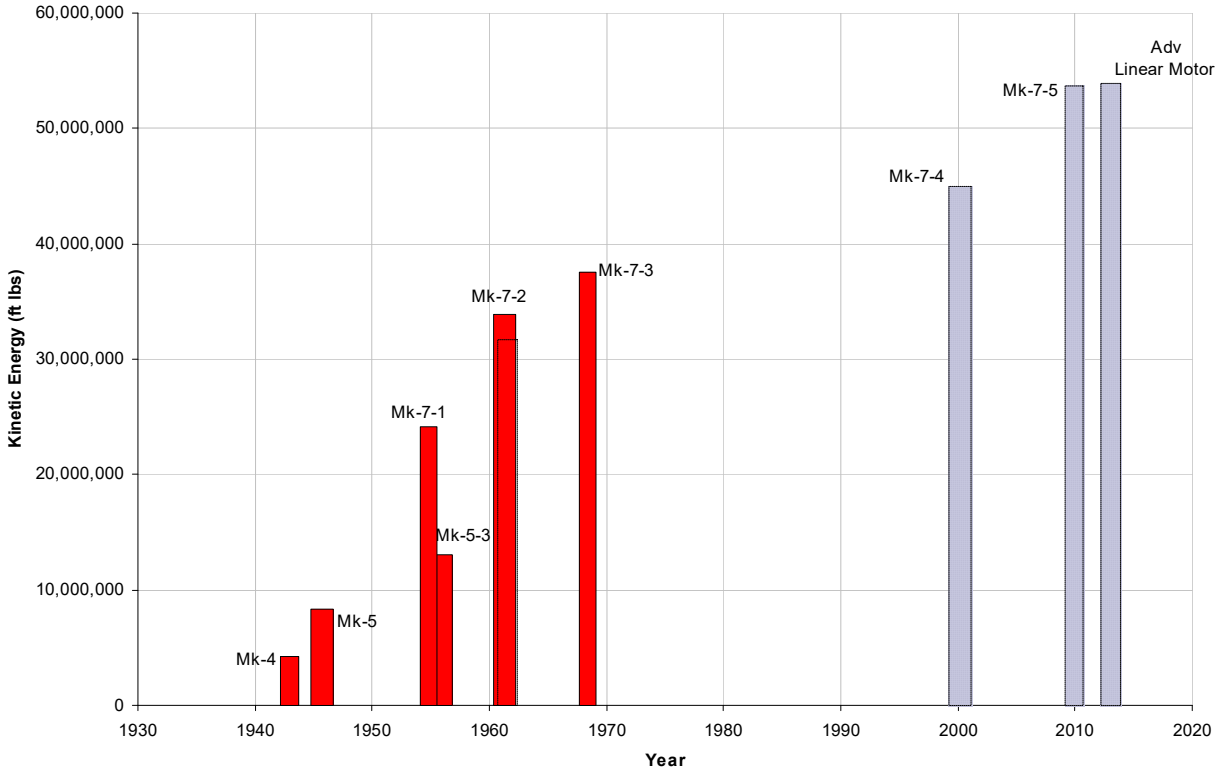
ARRESTING GEAR PERFORMANCE



Dr. Dimitri N. Mavris, Director ASDL
School of Aerospace Engineering
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dimitri.mavris@ae.gatech.edu

CV AIRCRAFT DESIGN CRITERIA

FOUR PRIMARY CRITERIA

- Geometric compatibility
- Adequate structural design for catapulting & arresting at critical loadings
- Lift, thrust and flying qualities for safe launch and approach
- Materials and design practices which can tolerate a hostile environment

Dr. Dimitri N. Mavris, Director ASDL
School of Aerospace Engineering
Georgia Institute of Technology
Atlanta, GA 30332-0150
dimitri.mavris@ae.gatech.edu

GEOMETRIC COMPATIBILITY

Dr. Dimitri N. Mavris, Director ASDL
School of Aerospace Engineering
Georgia Institute of Technology
Atlanta, GA 30332-0150
dimitri.mavris@ae.gatech.edu

GEOMETRIC COMPATIBILITY

DRIVEN BY:

- **Very limited space to conduct operations**
  (While maintaining safety and tempo)

- **Interfaces with CV equipment**
  (Esp. catapults and arresting gear)

- **Deck motions**
  (Aggravate most of the design challenges that exist for conventional A/C)

Dr. Dimitri N. Mavris, Director ASDL
School of Aerospace Engineering
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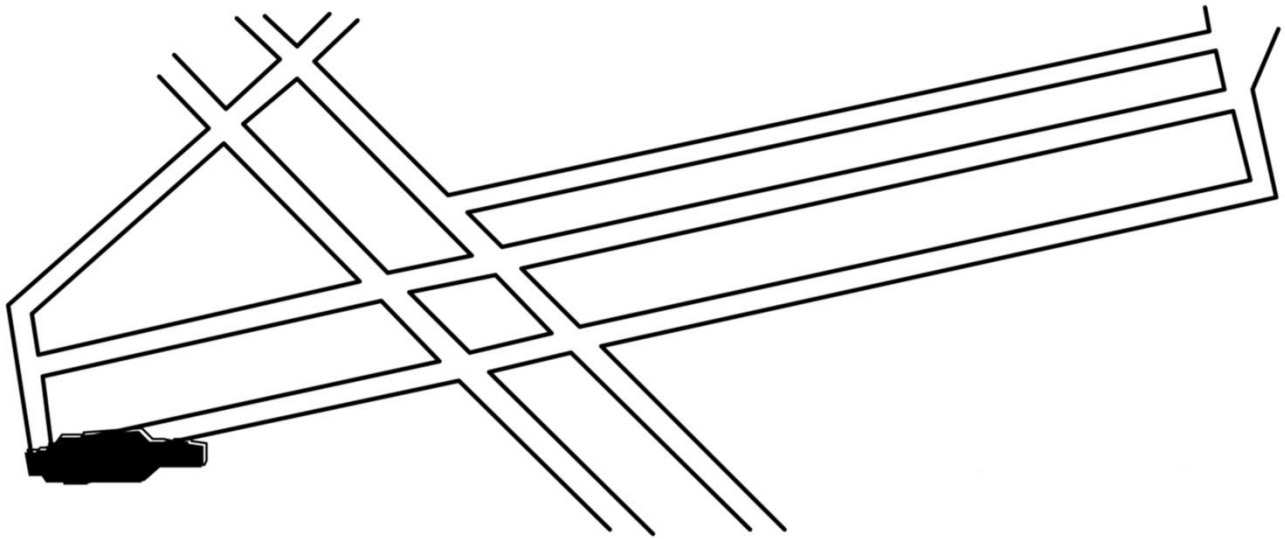
A Picture is Worth a Thousand Words

Comparative Scaling

USS Nimitz (CVN-68)
Overlaid on Typical Navy Airfield Runway (8000 Ft X 150 Ft)



Dr. Dimitri N. Mavris, Director ASDL
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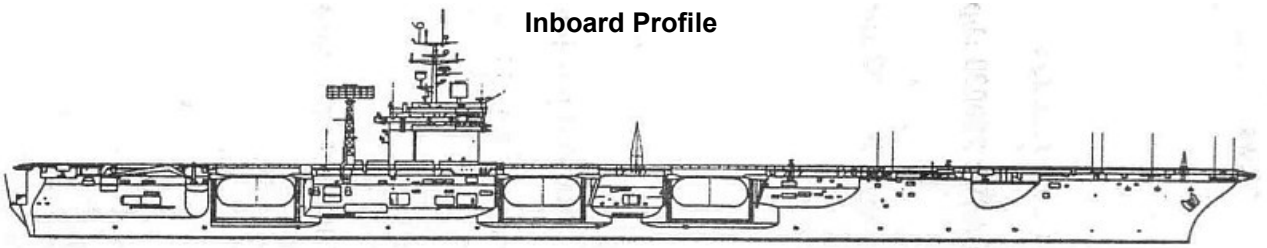
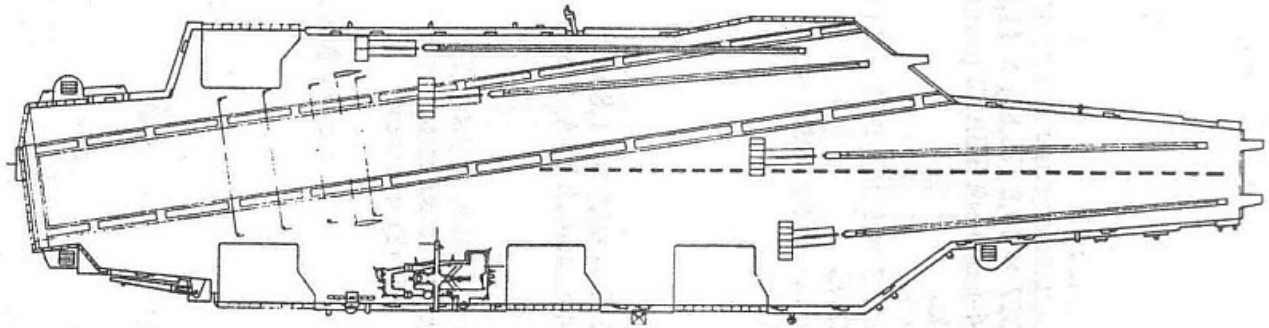
CVN 68 NIMITZ

Inboard Profile





Planview of Flight Deck

Dr. Dimitri N. Mavris, Director ASDL
School of Aerospace Engineering
Georgia Institute of Technology
Atlanta, GA 30332-0150
dimitri.mavris@ae.gatech.edu

CRITICAL DIMENSIONS CVN 68 NIMITZ

Flight Deck Length	1077 Ft
Flight Deck Width	251 Ft
Angle Deck Length	786 Ft
Catapult Stroke	302 Ft
Arresting Wire Span	120 Ft
Arresting Wire Runout	340 Ft
Barricade Runout	388 Ft
Hangar Deck Length	684 Ft
Hangar Deck Width	108 Ft
Hangar Deck Height	25 Ft
Door Width	76 Ft
Elevators (130 KLb Capacity)	52 Ft X 85 Ft

Dr. Dimitri N. Mavris, Director ASDL
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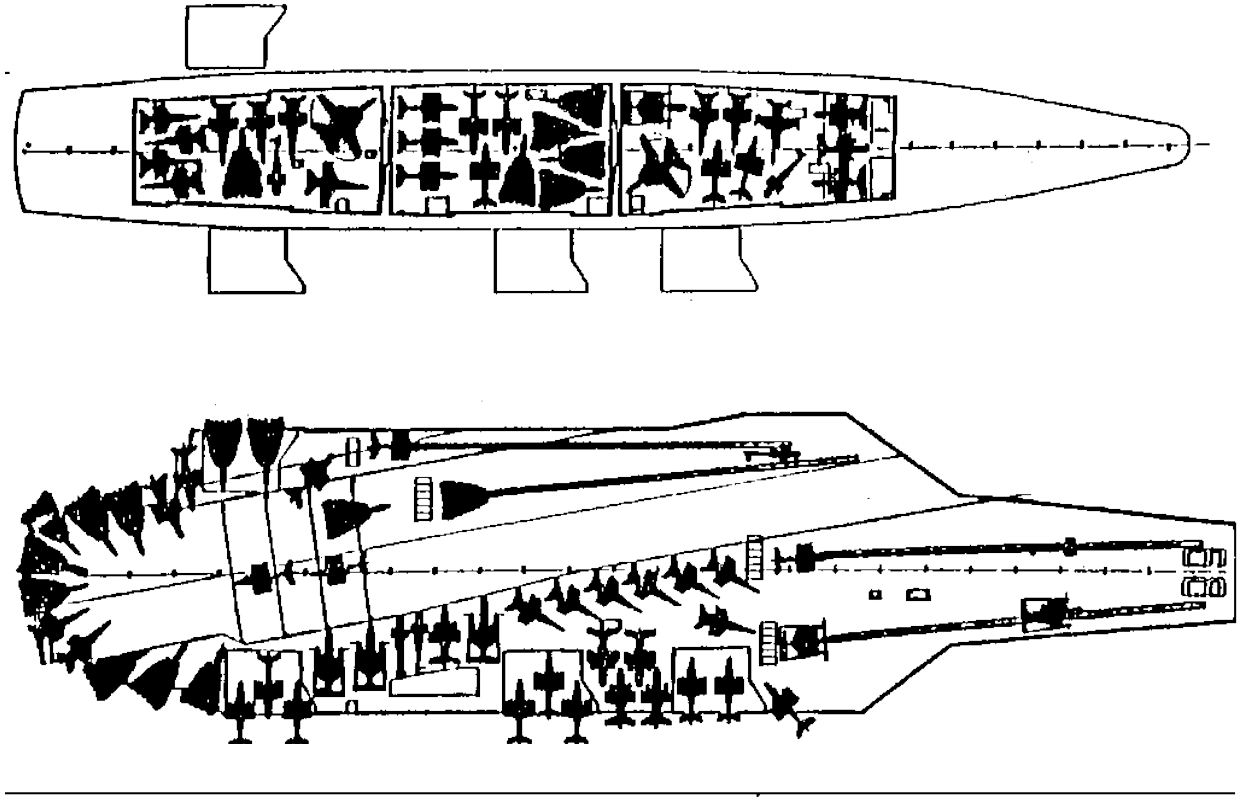
PRE-LAUNCH



Dr. Dimitri N. Mavris, Director ASDL
School of Aerospace Engineering
Georgia Institute of Technology
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dimitri.mavris@ae.gatech.edu

DESIGN FOR CONFINED SPACE

- Reduced Airspeed Operations for Ship Launch/Recovery
- No Flare Landings
  - Control Power
  - Strength
- Ship Catapult Interface
- Ship Arresting Gear Interface
- Tip Back/Roll Over Limits
- Elevator/Hangar Deck Limitations
- WEIGHT
- Aircraft Dimensions Length, Span, Height
- Folding Surfaces
- Accessibility
  - Servicing
  - Maintenance
  - Weapon Loading
- Maintenance in Shadow e.g. Engine Change
- On Deck Maneuverability and Visibility

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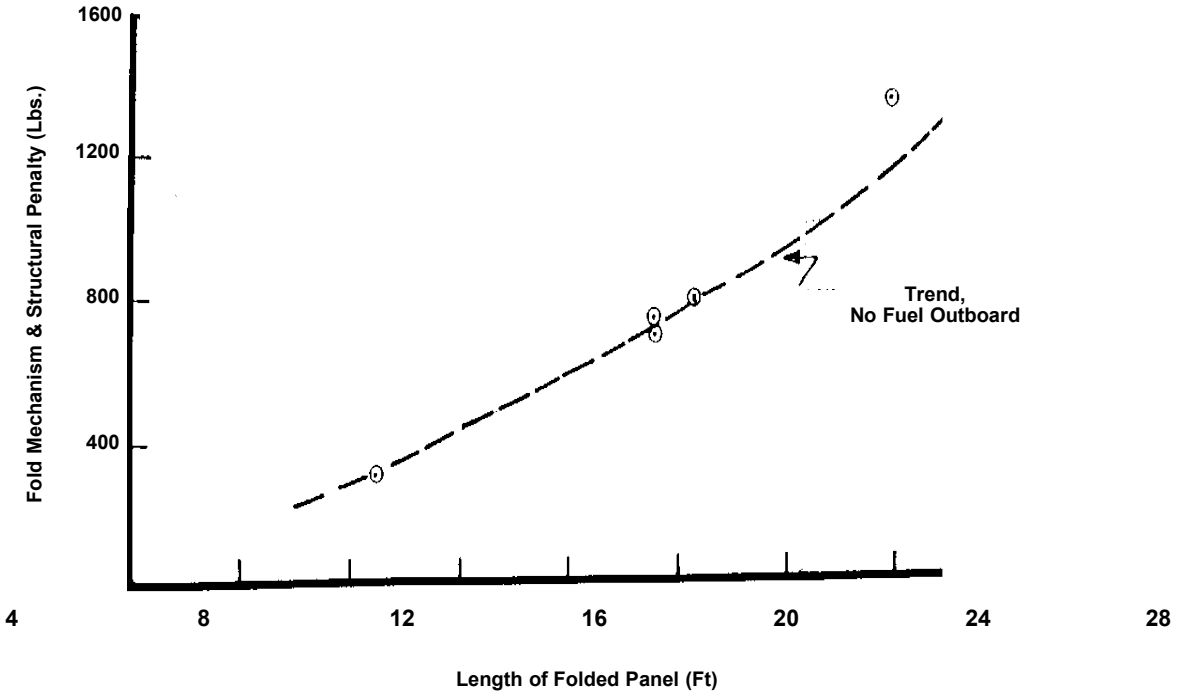
dimitri.mavris@ae.gatech.edu

WING FOLD PENALTY



Dr. Dimitri N. Mavris, Director ASDL
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dimitri.mavris@ae.gatech.edu

SPOTTING FACTOR

- Measure of deck space occupied by aircraft
- Complex Function of:
  - Size
  - Geometry
  - Overhang Etc.
- Empirically determined
- Current baseline F/A-18C = 1.0
- "Integer effects"

  To add <u>one</u> aircraft of 1.5 spot factor could require that <u>two</u> aircraft of 1.2 spot factor be taken out of the air wing

Dr. Dimitri N. Mavris, Director ASDL
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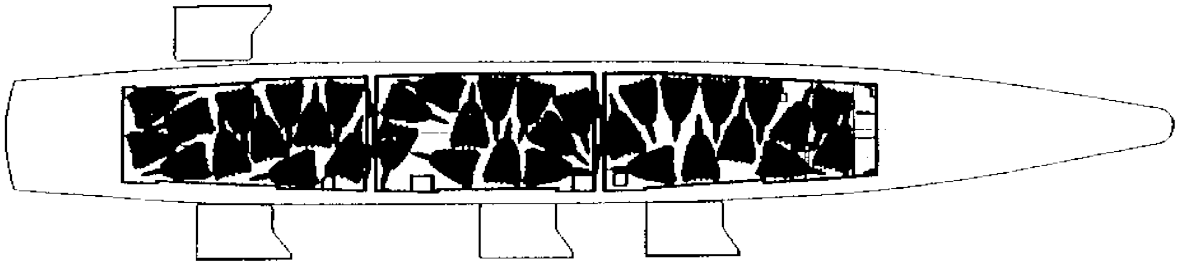
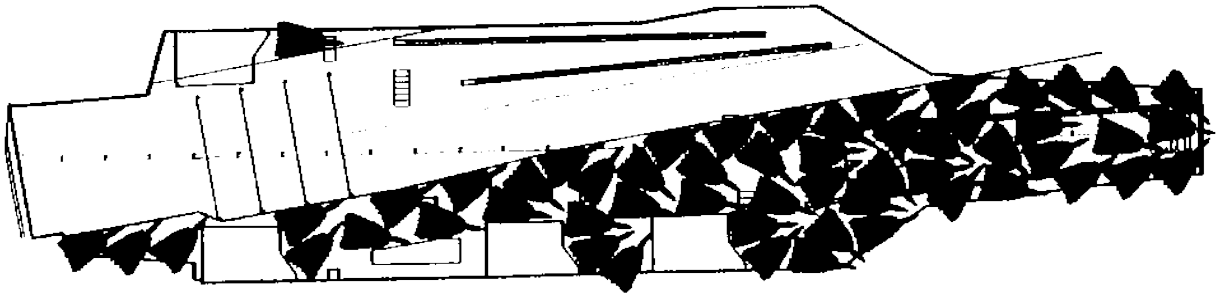
dimitri.mavris@ae.gatech.edu

MAXIMUM DENSITY SPOTTING



Flight Deck	56 A/C
Hangar Deck	35 A/C
Total	91 A/C



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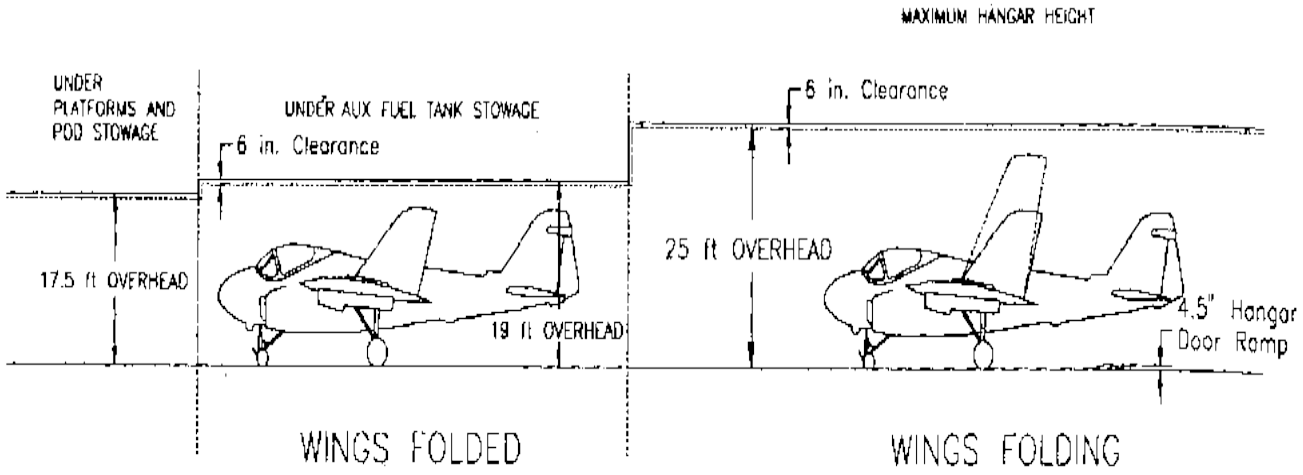
HANGAR BAY HEIGHT CLEARANCES



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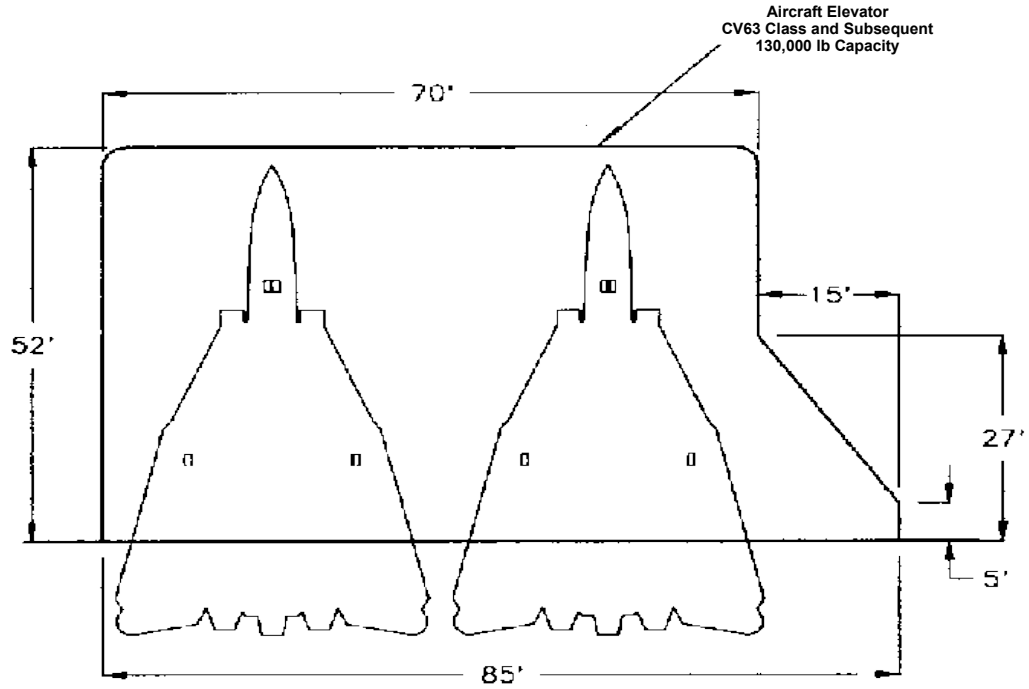
ELEVATOR SIZING



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Georgia Institute of Technology
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dimitri.mavris@ae.gatech.edu

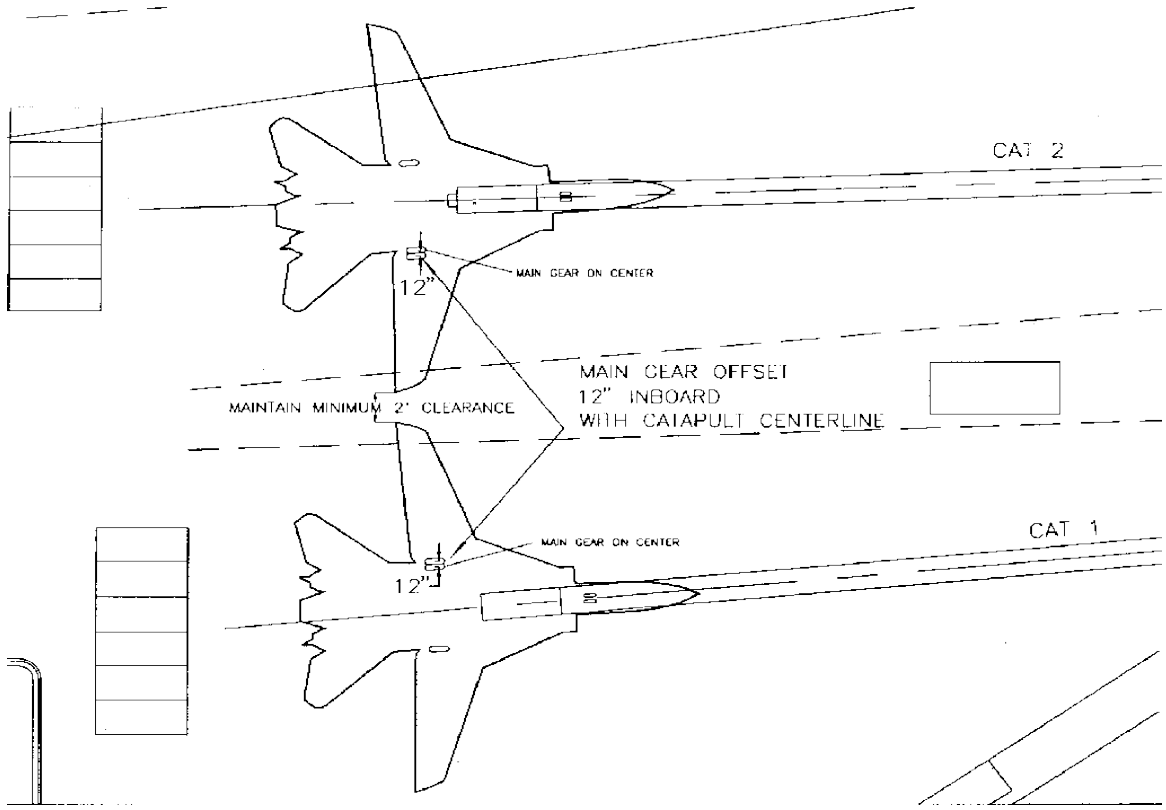
GEOMETRIC COMPATIBILITY FOR LAUNCH

Clearances Required for Launching

- Aircraft and stores must clear deck obstructions (6” clearance, flat tire, rolled attitude)
- Able to spread wings of both aircraft on adjacent bow catapults
- Adequate distance from exhaust nozzle(s) to JBD

Dr. Dimitri N. Mavris, Director ASDL
School of Aerospace Engineering
Georgia Institute of Technology
Atlanta, GA 30332-0150
dimitri.mavris@ae.gatech.edu

WINGTIP CLEARANCE



Dr. Dimitri N. Mavris, Director ASDL
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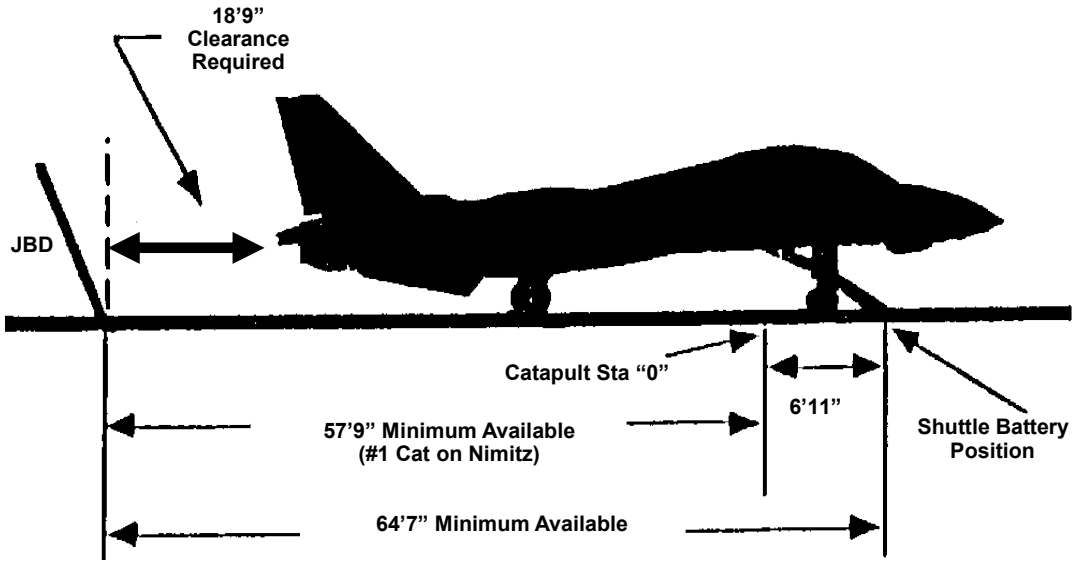
dimitri.mavris@ae.gatech.edu

JET BLAST DEFLECTOR (JBD) CLEARANCE

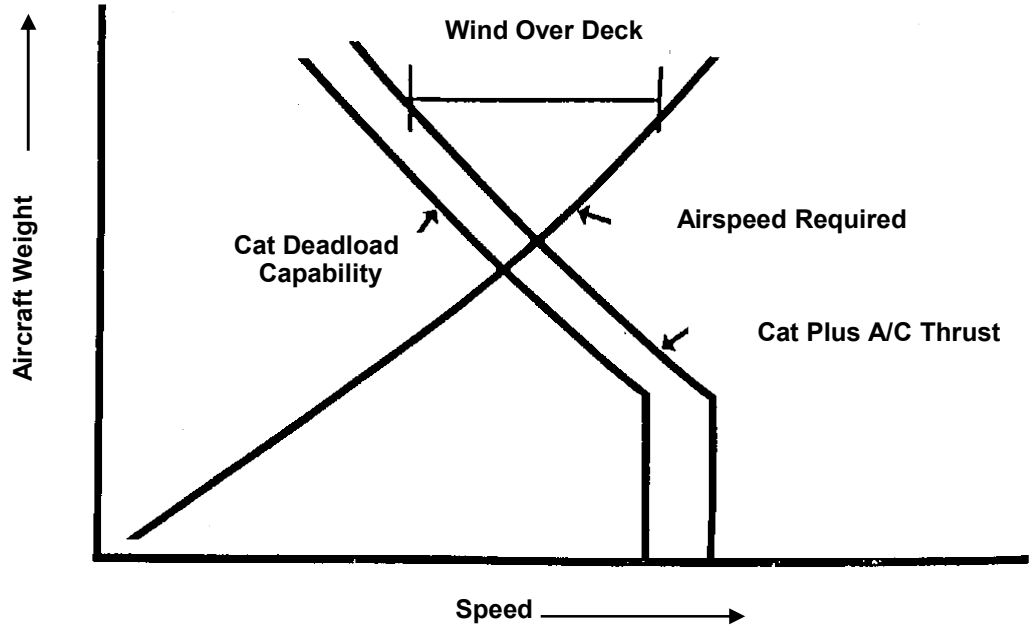


- Aircraft Launch Bar to Tail Distance Constrained By JBD Clearance to 45'40"
  - Typical Aircraft: F-14A- 45.9'
    F/A-18A- 38.6'
    F/A-18E- 41.7'

Dr. Dimitri N. Mavris, Director ASDL
School of Aerospace Engineering
Georgia Institute of Technology
Atlanta, GA 30332-0150
dimitri.mavris@ae.gatech.edu

LAUNCHING

LAUNCH WIND OVER DECK



Dr. Dimitri N. Mavris, Director ASDL
School of Aerospace Engineering
Georgia Institute of Technology
Atlanta, GA 30332-0150
dimitri.mavris@ae.gatech.edu

LAUNCH WIND OVER DECK

- **Wind Over Deck Defined on Previous Chart Applies to:**
  - **Engineering Design**
  - **Contractual Guarantees**
  - **Flight Testing**
- **The Fleet Adds 15 Knots to This Value for Operational Factors:**
  - **Gusts**
  - **Ship Motion**
  - **Equipment Variations**
  - **Etc.**
- **Most Fleet Personnel Talk in Terms of the Operational WOD Not Design WOD**

Dr. Dimitri N. Mavris, Director ASDL
School of Aerospace Engineering
Georgia Institute of Technology
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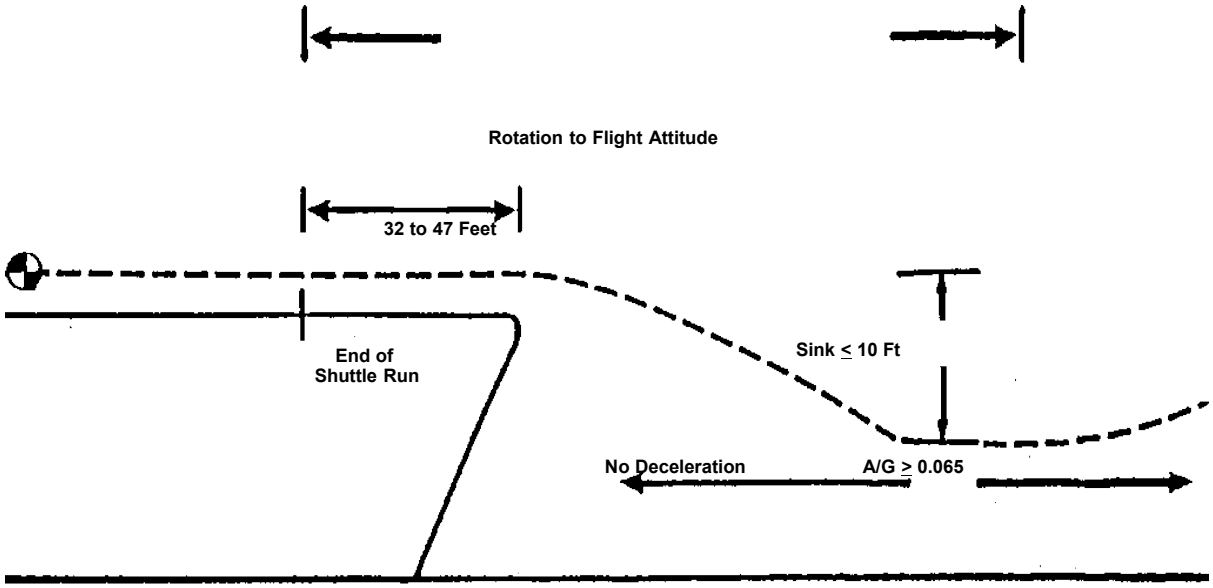
dimitri.mavris@ae.gatech.edu

LAUNCH FLIGHT PATH



Dr. Dimitri N. Mavris, Director ASDL
School of Aerospace Engineering
Georgia Institute of Technology
Atlanta, GA 30332-0150
dimitri.mavris@ae.gatech.edu

CATAPULT SPEED CRITERIA

- Longitudinal acceleration of at least 1.24 kts/sec
- Center of gravity sink not to exceed 10 feet
- Nose up pitch rate not to exceed 12 deg/sec,
- Nose down pitch rate not to exceed 2.5 deg/sec (automatic flight control system)
- Rotation not to exceed 0.9 maximum lift
- Minimum control speed with one engine failed
- Rate of climb with one engine failed

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Georgia Institute of Technology
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dimitri.mavris@ae.gatech.edu

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School of Aerospace Engineering
Georgia Institute of Technology
Atlanta, GA 30332-0150
dimitri.mavris@ae.gatech.edu

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School of Aerospace Engineering
Georgia Institute of Technology
Atlanta, GA 30332-0150
dimitri.mavris@ae.gatech.edu

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School of Aerospace Engineering
Georgia Institute of Technology
Atlanta, GA 30332-0150
dimitri.mavris@ae.gatech.edu

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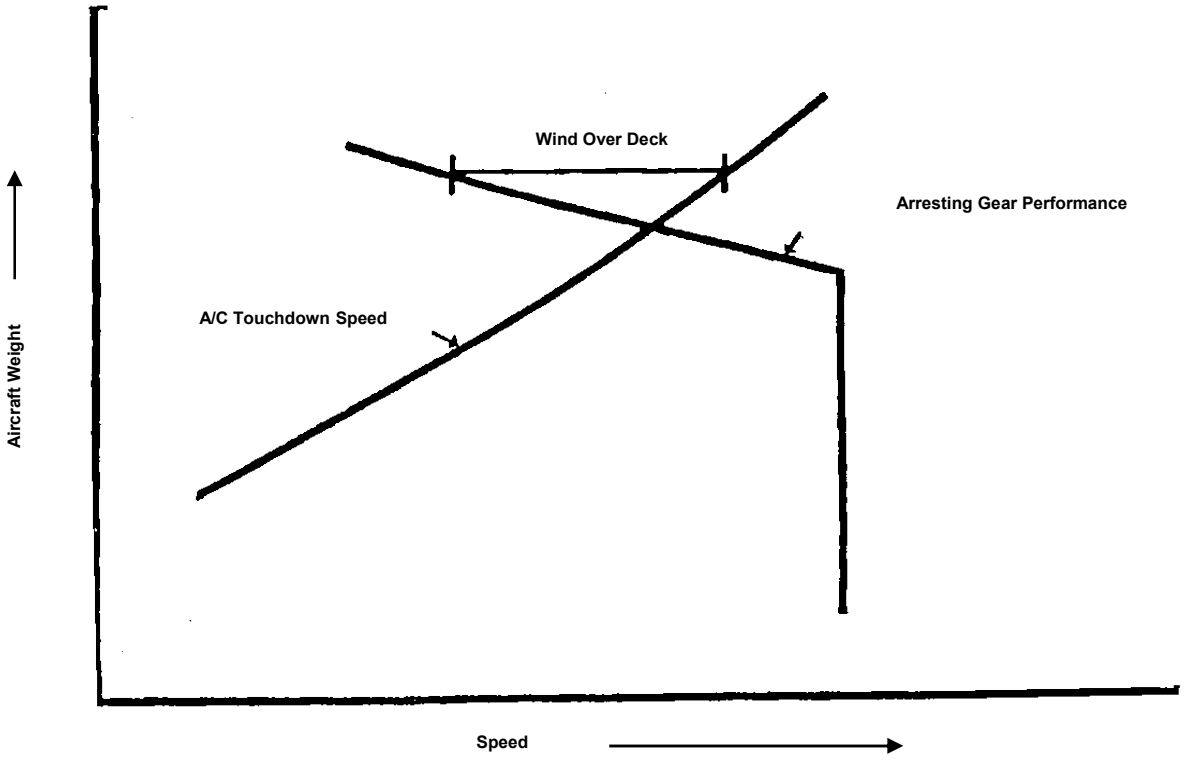
Dr. Dimitri N. Mavris, Director ASDL
School of Aerospace Engineering
Georgia Institute of Technology
Atlanta, GA 30332-0150
dimitri.mavris@ae.gatech.edu

RECOVERY

Dr. Dimitri N. Mavris, Director ASDL
School of Aerospace Engineering
Georgia Institute of Technology
Atlanta, GA 30332-0150
dimitri.mavris@ae.gatech.edu

RECOVERY WIND OVER DECK (Recovery Headwind)



Dr. Dimitri N. Mavris, Director ASDL
School of Aerospace Engineering
Georgia Institute of Technology
Atlanta, GA 30332-0150
dimitri.mavris@ae.gatech.edu

APPROACH SPEED CRITERIA

- LONGITUDINAL ACCELERATION (WAVEOFF)
  - 3 KNOTS PER SECOND IN 2.5 SECONDS
- STALL MARGIN
  - APPROACH SPEED AT LEAST 10% ABOVE STALL SPEED
- VISIBILITY
  - SEE STERN WATERLINE WHEN INTERCEPTING 4° GLIDESLOPE AT 600’ ALTITUDE
- SATISFY STABILITY AND CONTROL REQUIREMENTS (MIL-STD-1797)
- GLIDEPATH CORRECTION MANEUVER
  - ACHIEVE 50’ HIGHER GLIDEPATH IN 5 SECONDS WITHOUT USING THRUST AND USING ½ OF ADDITIONAL AVAILABLE LIFT
- ENGINE RESPONSE
  - FOR STEP THROTTLE COMMANDS FOR ± 2.3 KNOTS/SECONDS ACHIEVE 90% IN 1.2 SECONDS

Dr. Dimitri N. Mavris, Director ASDL
School of Aerospace Engineering
Georgia Institute of Technology
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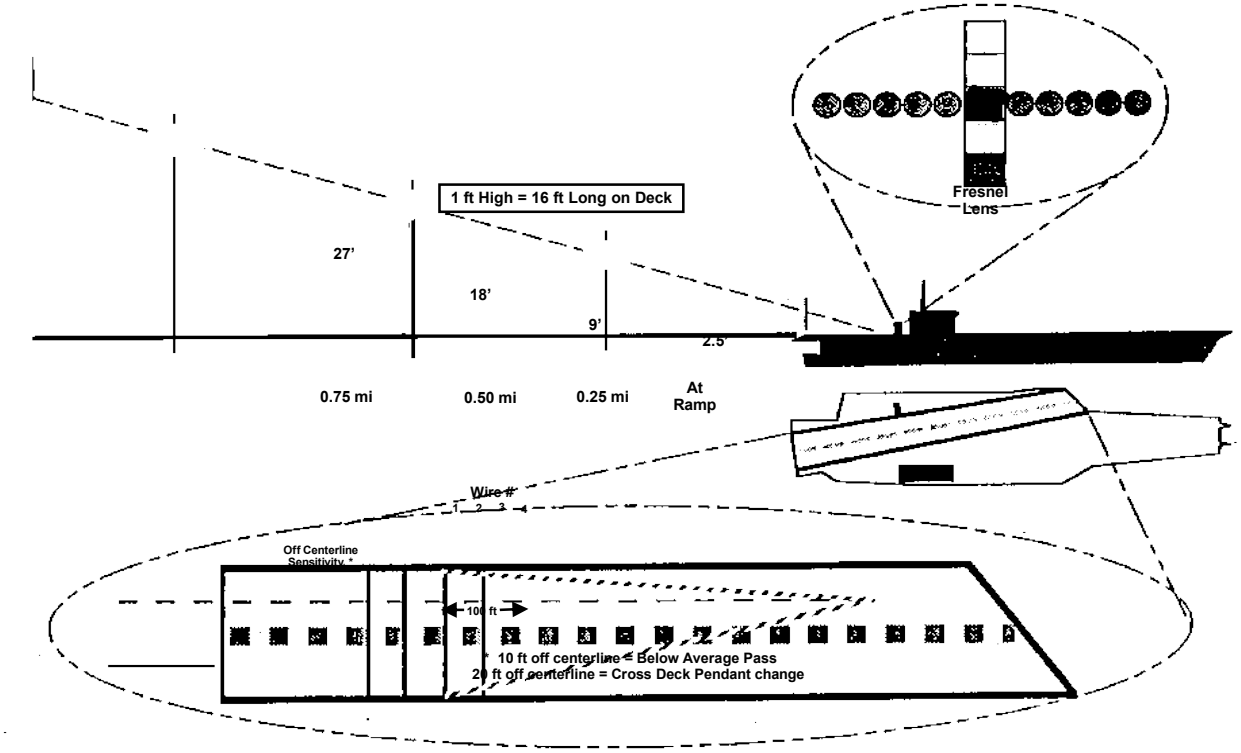
dimitri.mavris@ae.gatech.edu

GLIDE SLOPE / LINE-UP CONTROL



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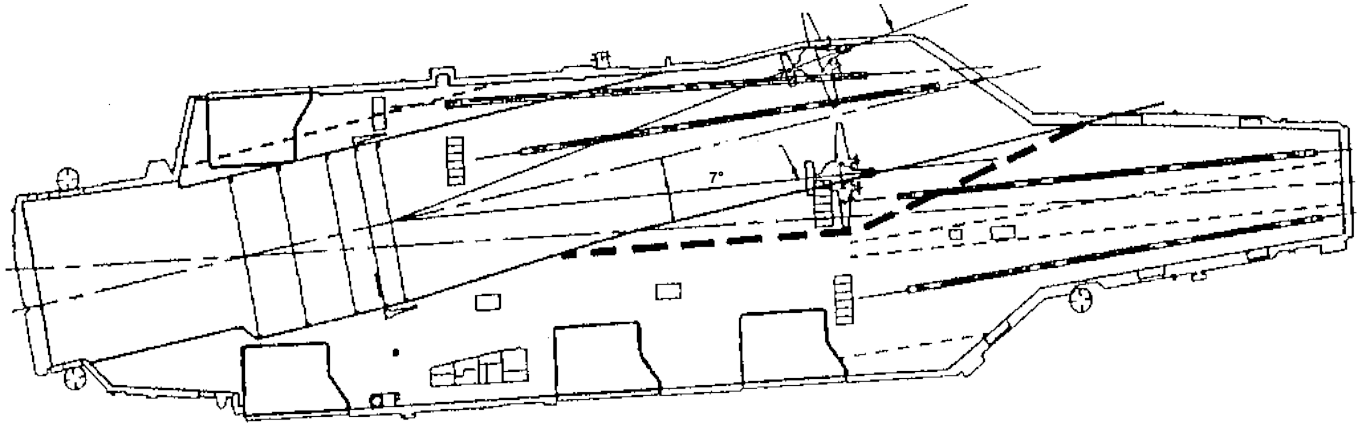
Georgia Institute of Technology
Atlanta, GA 30332-0150
dimitri.mavris@ae.gatech.edu

CVN 68
MK7 MOD3 ARRESTING GEAR(345 FT TO TAIL HOOK)
CONVENTIONAL 4 WIRE SYSTEM



Dr. Dimitri N. Mavris, Director ASDL
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Georgia Institute of Technology
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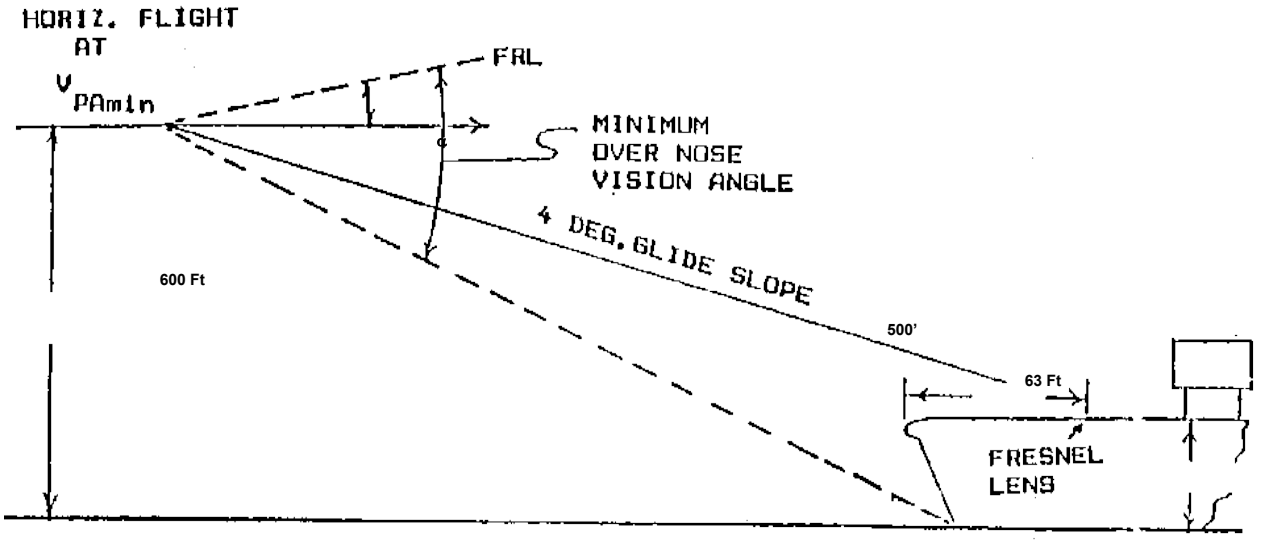
CARRIER APPROACH VISION



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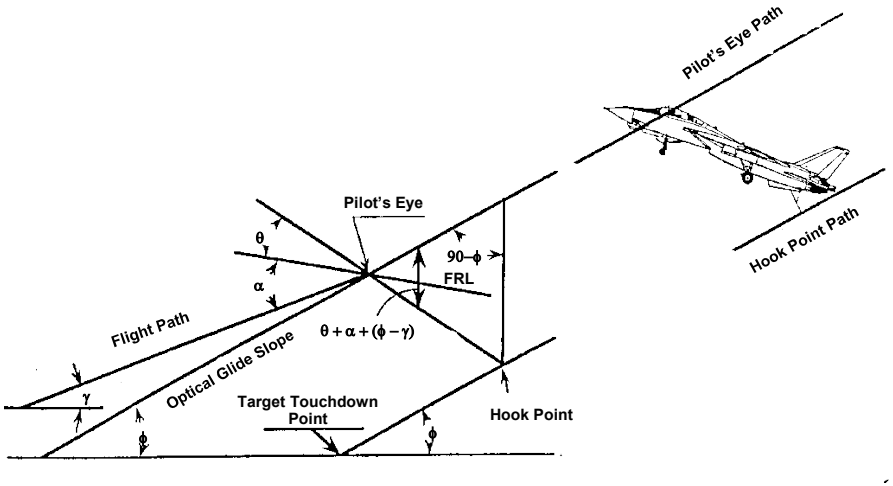
HOOK-TO-EYE GEOMETRY



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