

Aircraft Design and Constraint Analysis for Carrier Operations

AMY DWYER FRANK O'BRIMSKI
CONCEPTUAL DESIGN DIVISION
NAVAIR SYSCOM

PURPOSE

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

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

ENHANCE SORTIE GENERATION RATE

CARRIER EQUIPMENT

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

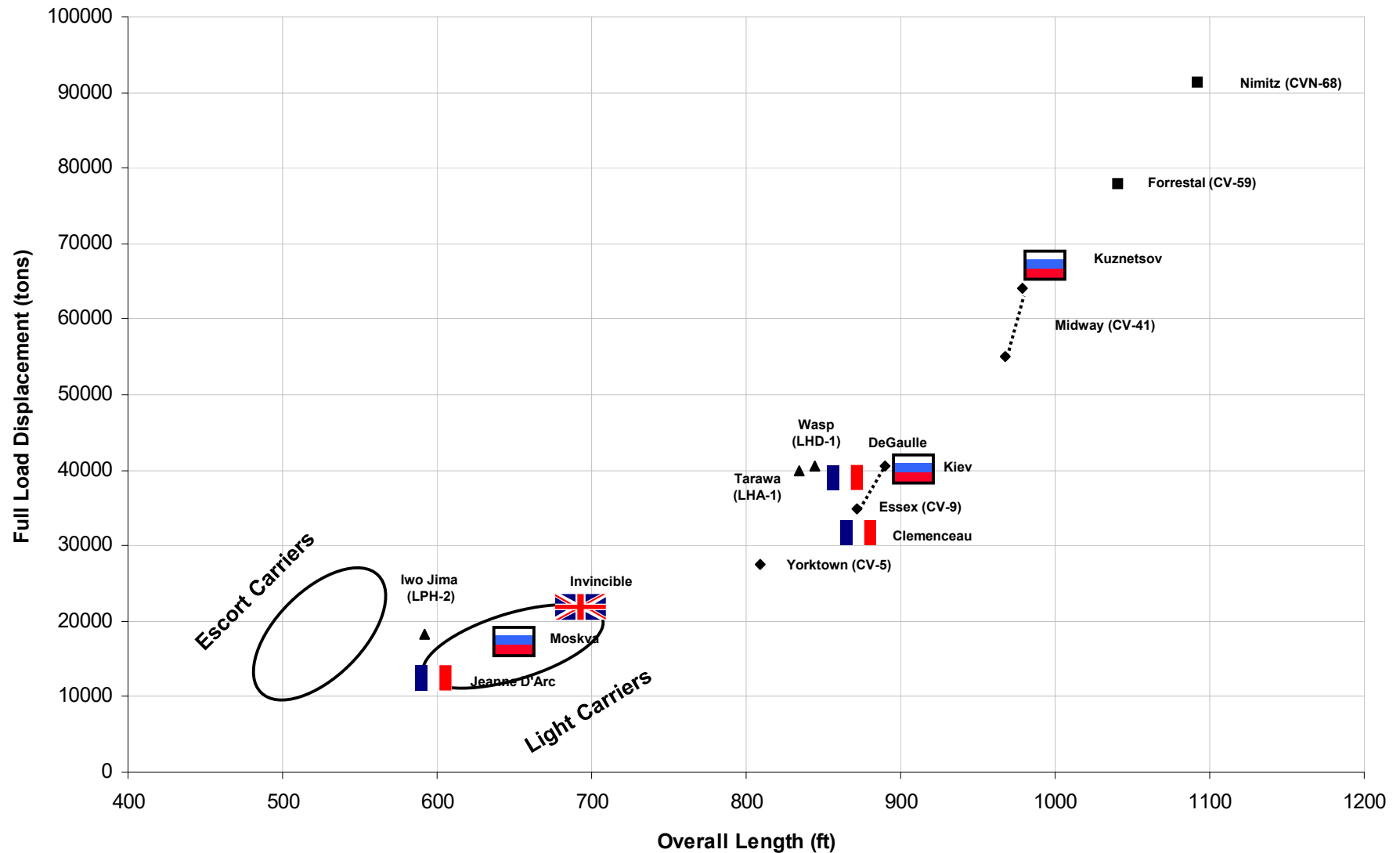
AIRCRAFT DESIGN

- 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

OPERATING CONDITIONS

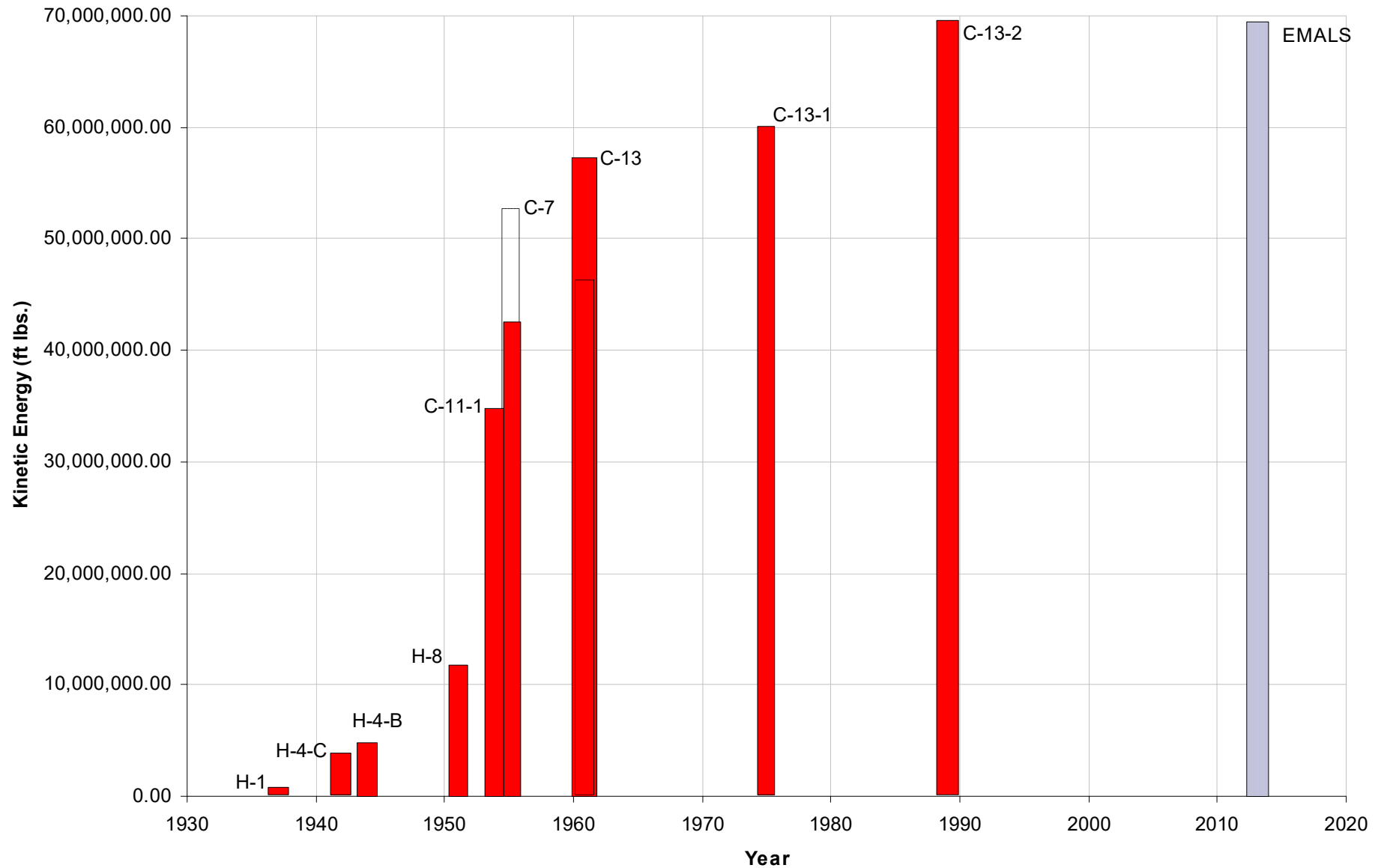
- **SPACE COMPRESSION**
 - Confined Area to Conduct Ops
 - Thermal and Acoustic Hazards
- **MARITIME ENVIRONMENT**
 - High Winds
 - Moving Deck
 - Moisture on Deck
- **DENSE ELECTROMAGNETIC ENVIRONMENT**

AIRCRAFT CARRIER DESIGN TRENDS

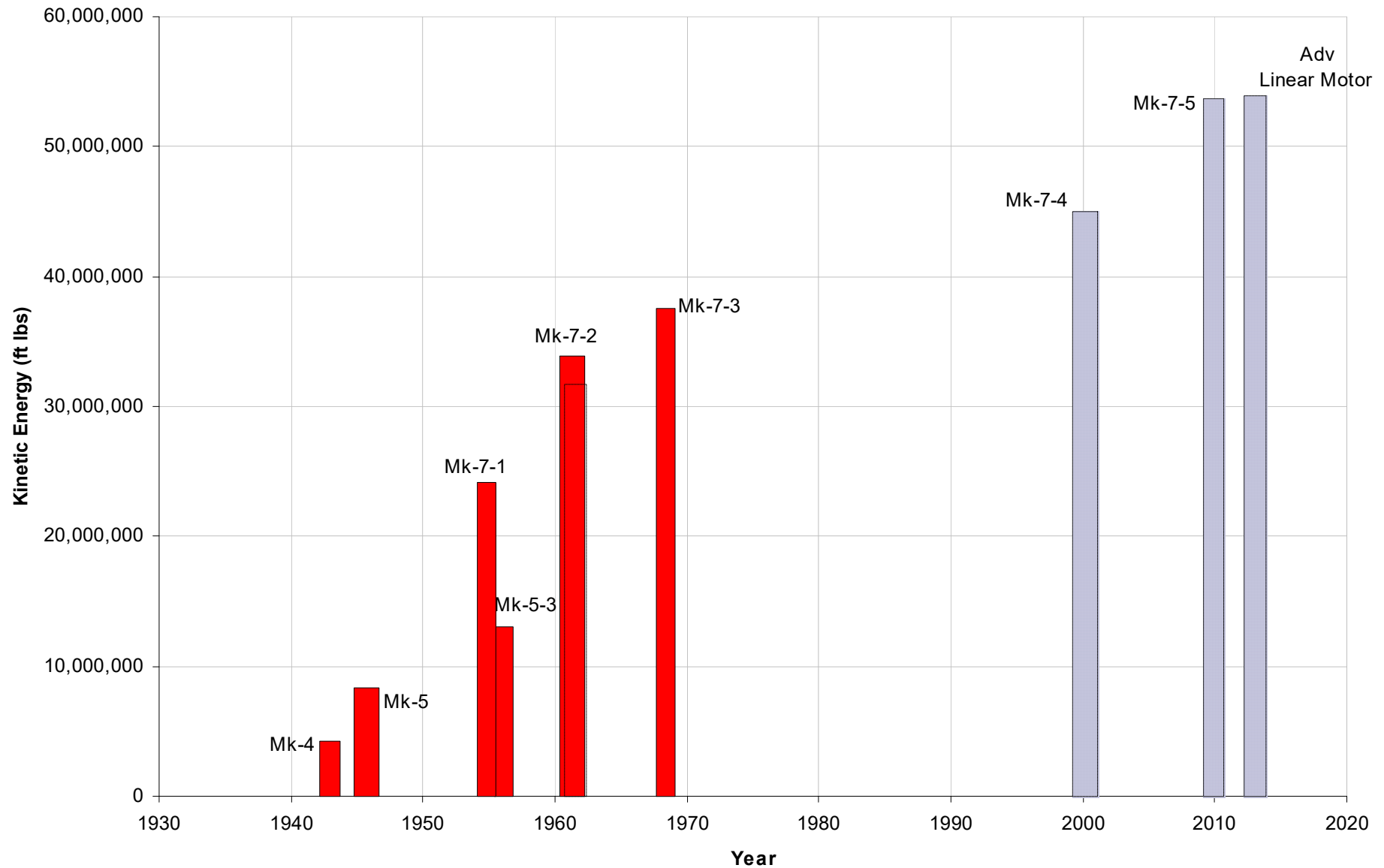


AIRCRAFT LAUNCH AND RECOVERY EQUIPMENT

CATAPULT PERFORMANCE



ARRESTING GEAR PERFORMANCE



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**

GEOMETRIC COMPATIBILITY

GEOMETRIC COMPATIBILITY

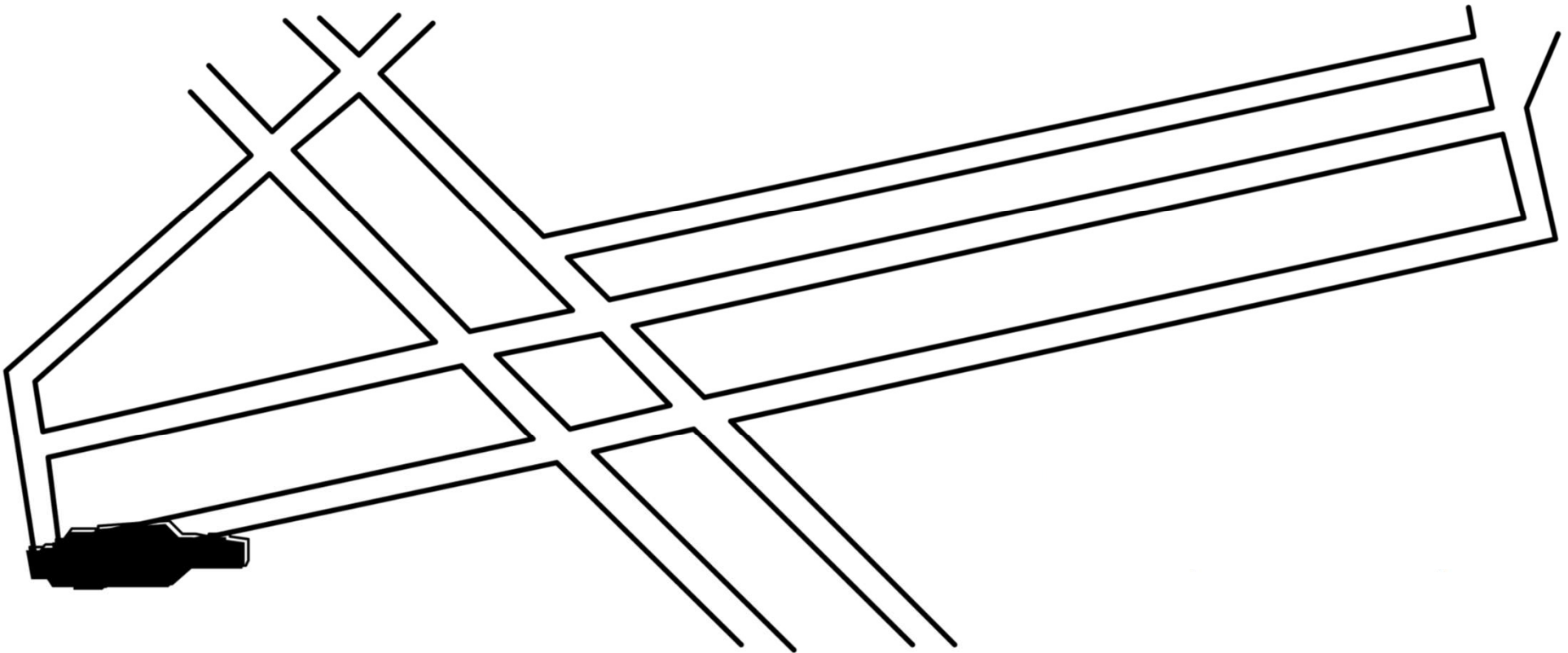
DRIVEN BY:

- **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)

A Picture is Worth a Thousand Words

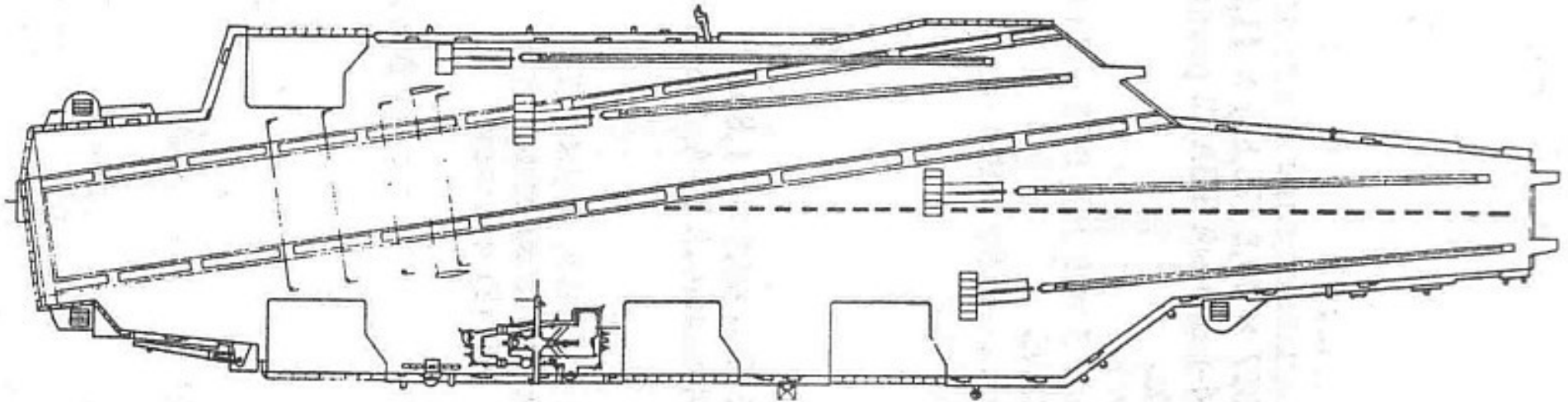
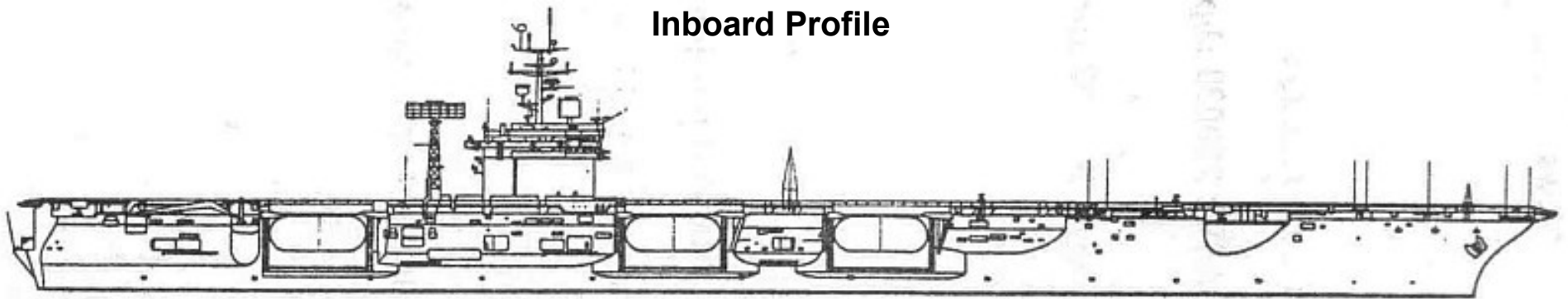
Comparative Scaling

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



CVN 68 NIMITZ

Inboard Profile



Planview of Flight Deck

CRITICAL DIMENSIONS CVN 68 NIMITZ

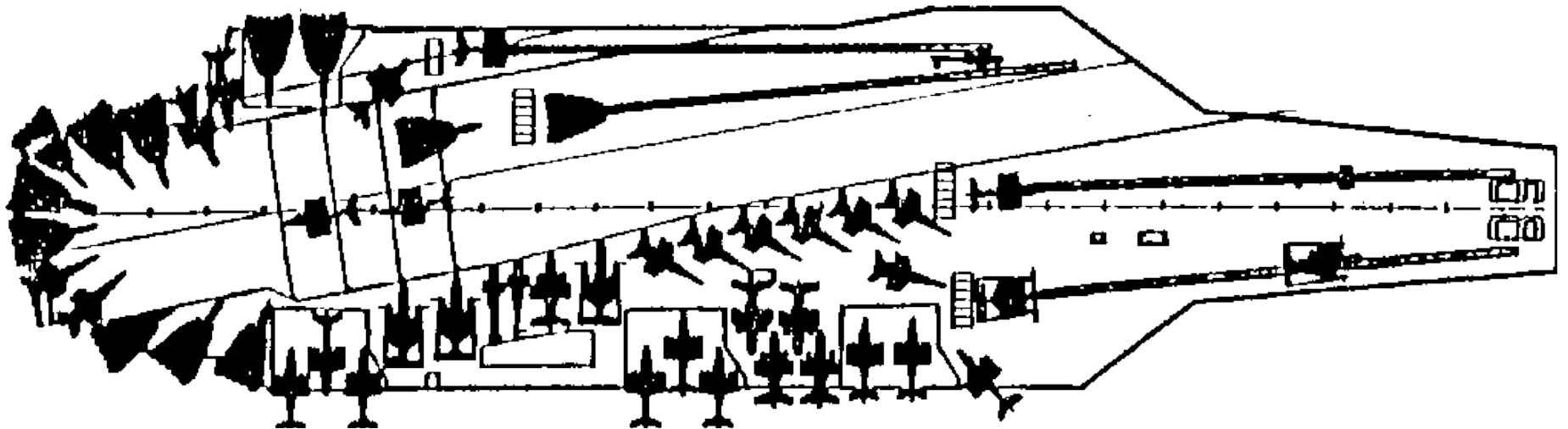
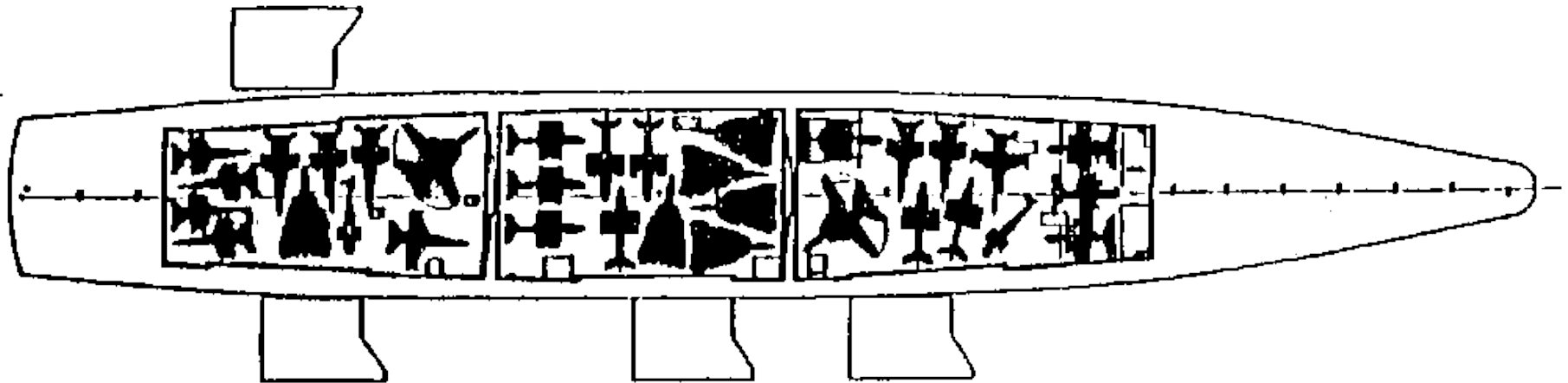
Flight Deck Length	1077 Ft
Flight Deck Width	251 Ft
Angle Deck Length	786 Ft

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
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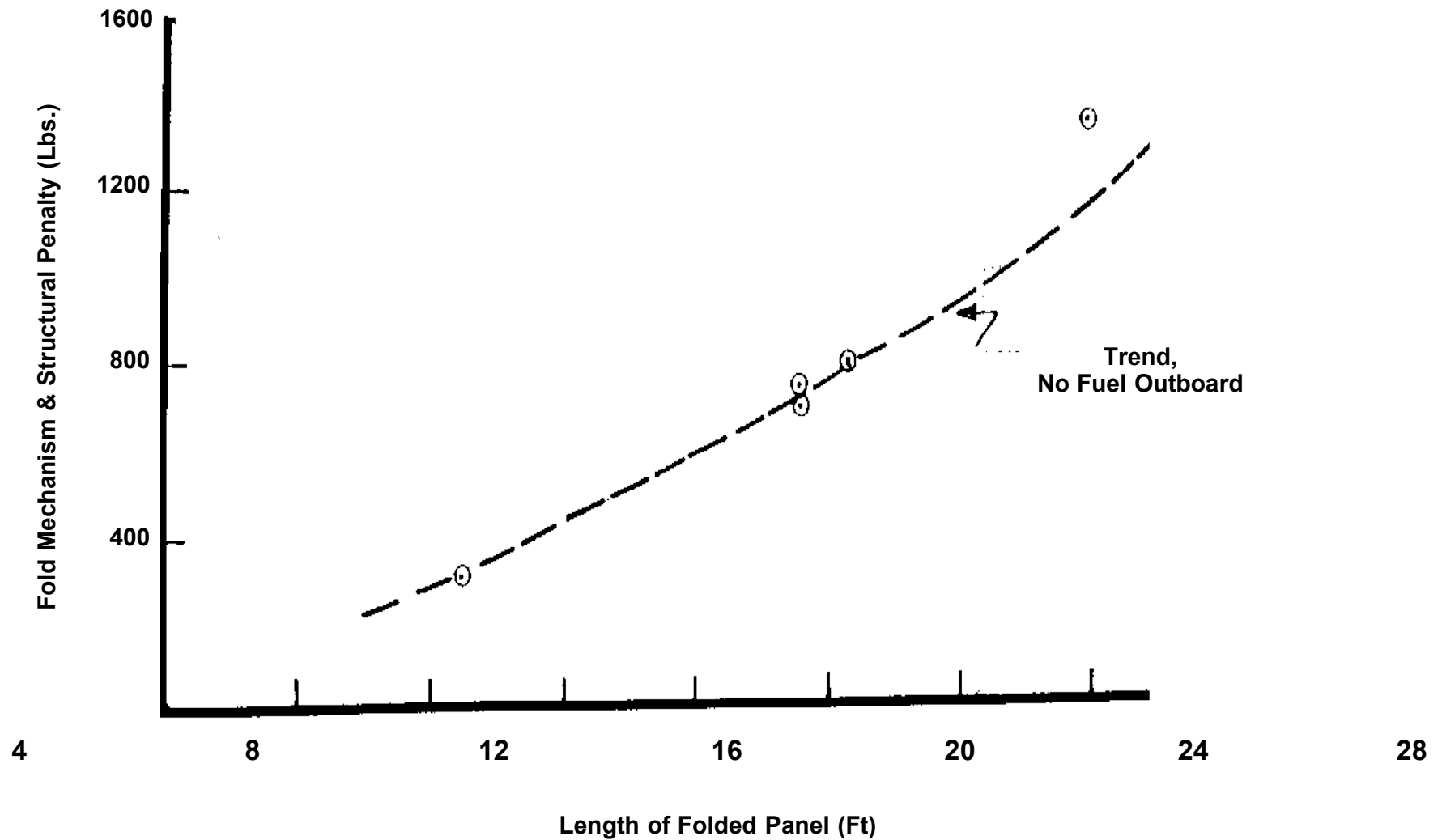
PRE-LAUNCH



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**

WING FOLD PENALTY

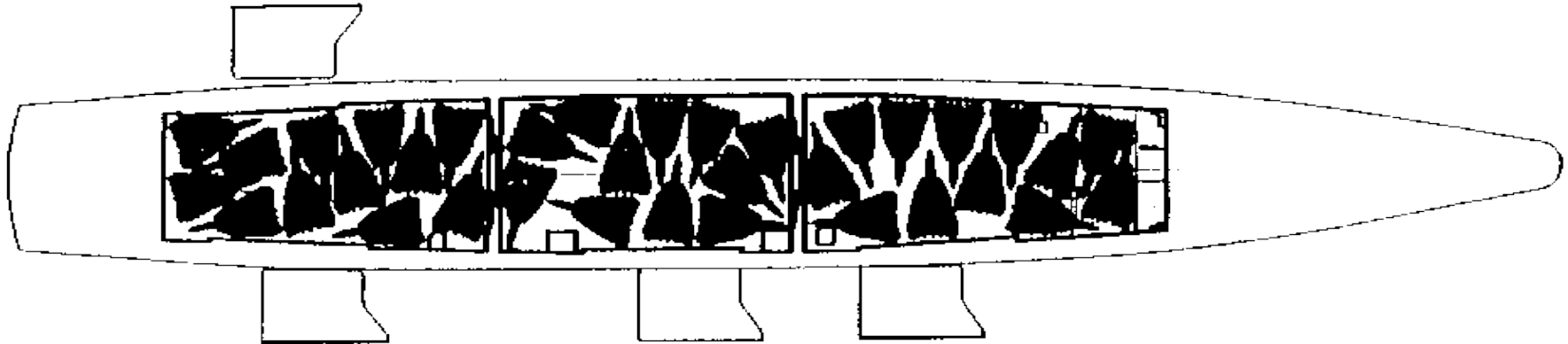


SPOTTING FACTOR

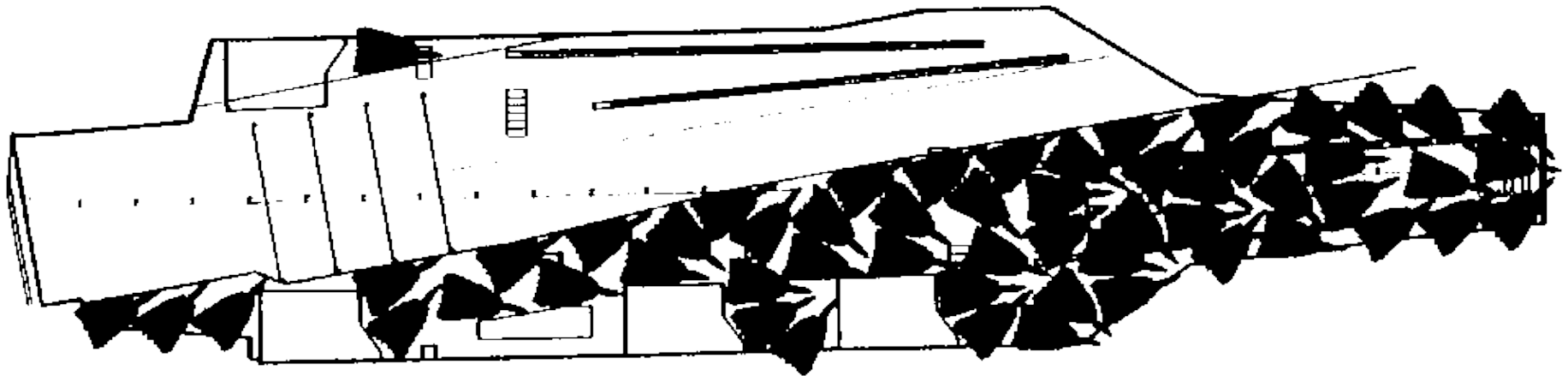
- Measure of deck space occupied by aircraft
- Complex Function of:
 - Size
 - Geometry
 - Overhang Etc.
- Empirically determined
- Current baseline F/A-18C = 1.0
- “Integer effects”

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

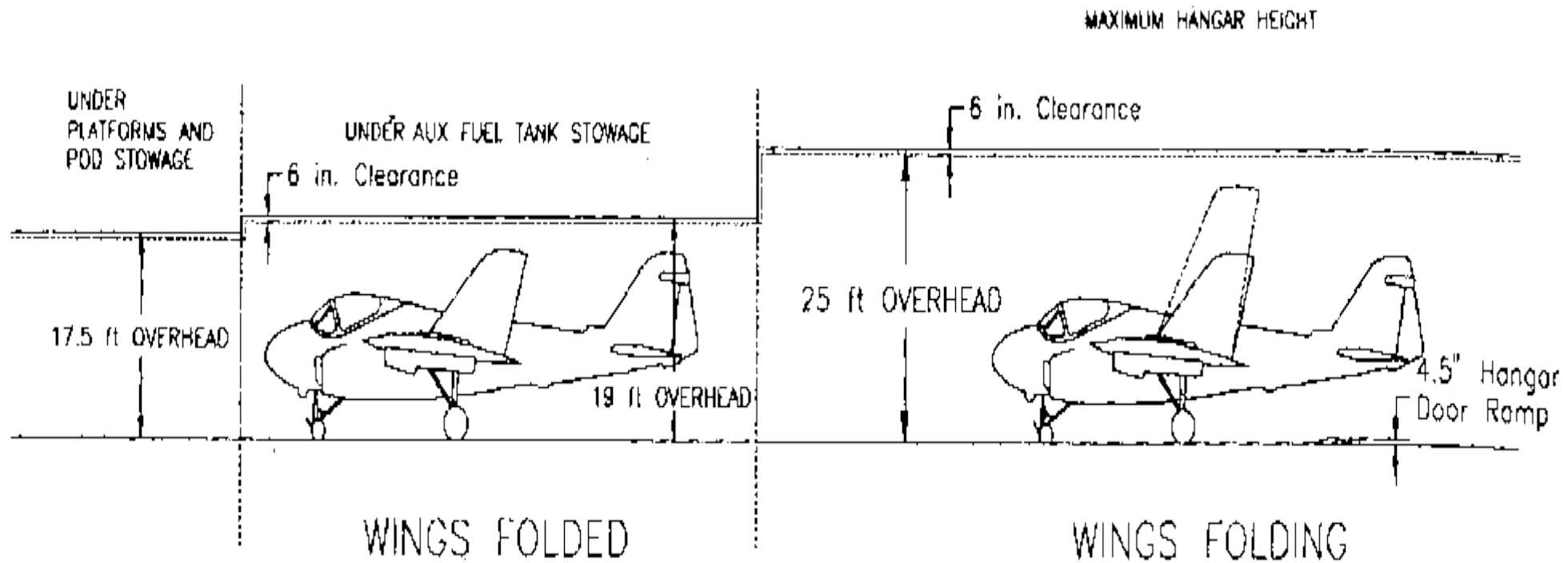
MAXIMUM DENSITY SPOTTING



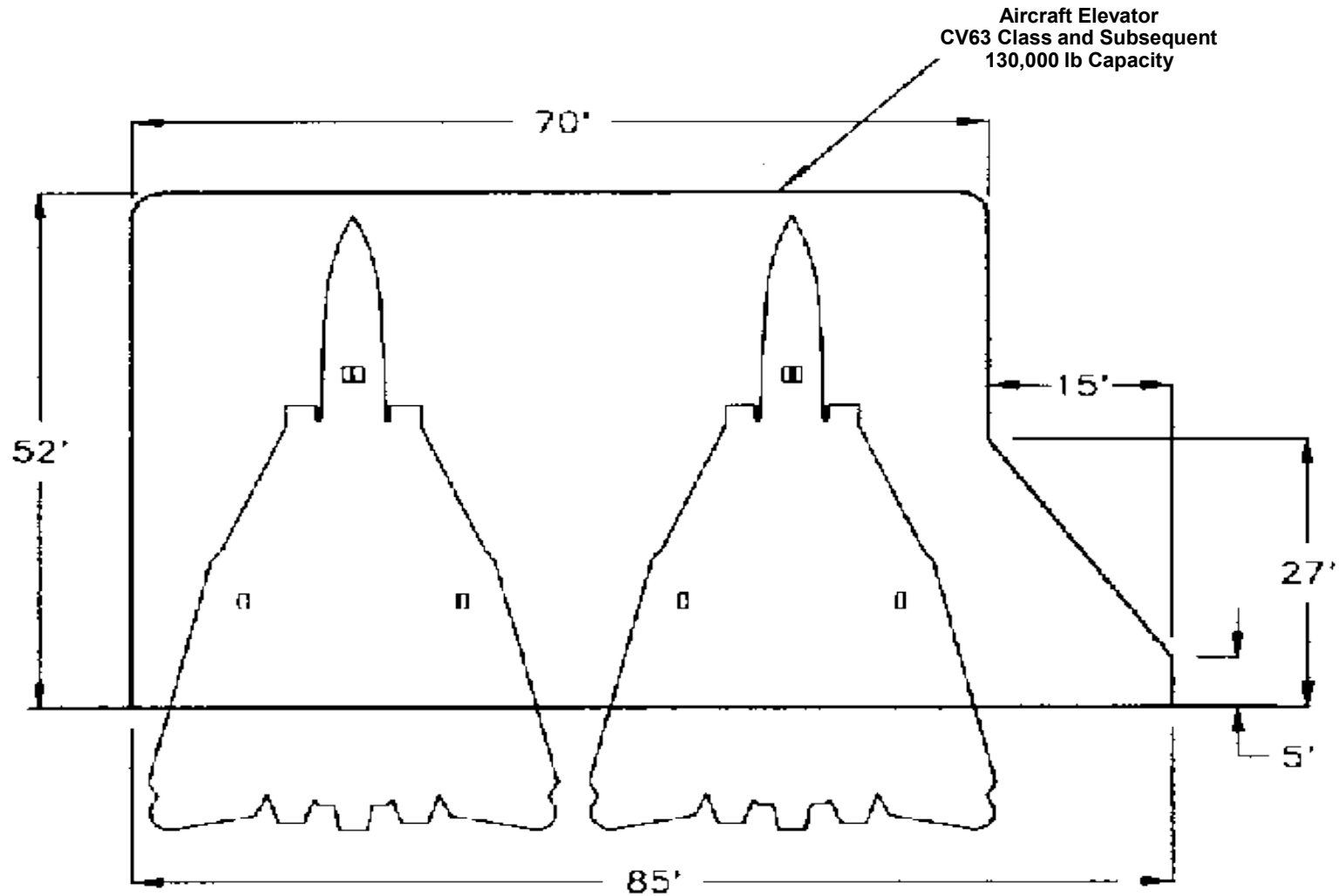
Flight Deck	56 A/C
Hangar Deck	35 A/C
Total	91 A/C



HANGAR BAY HEIGHT CLEARANCES



ELEVATOR SIZING

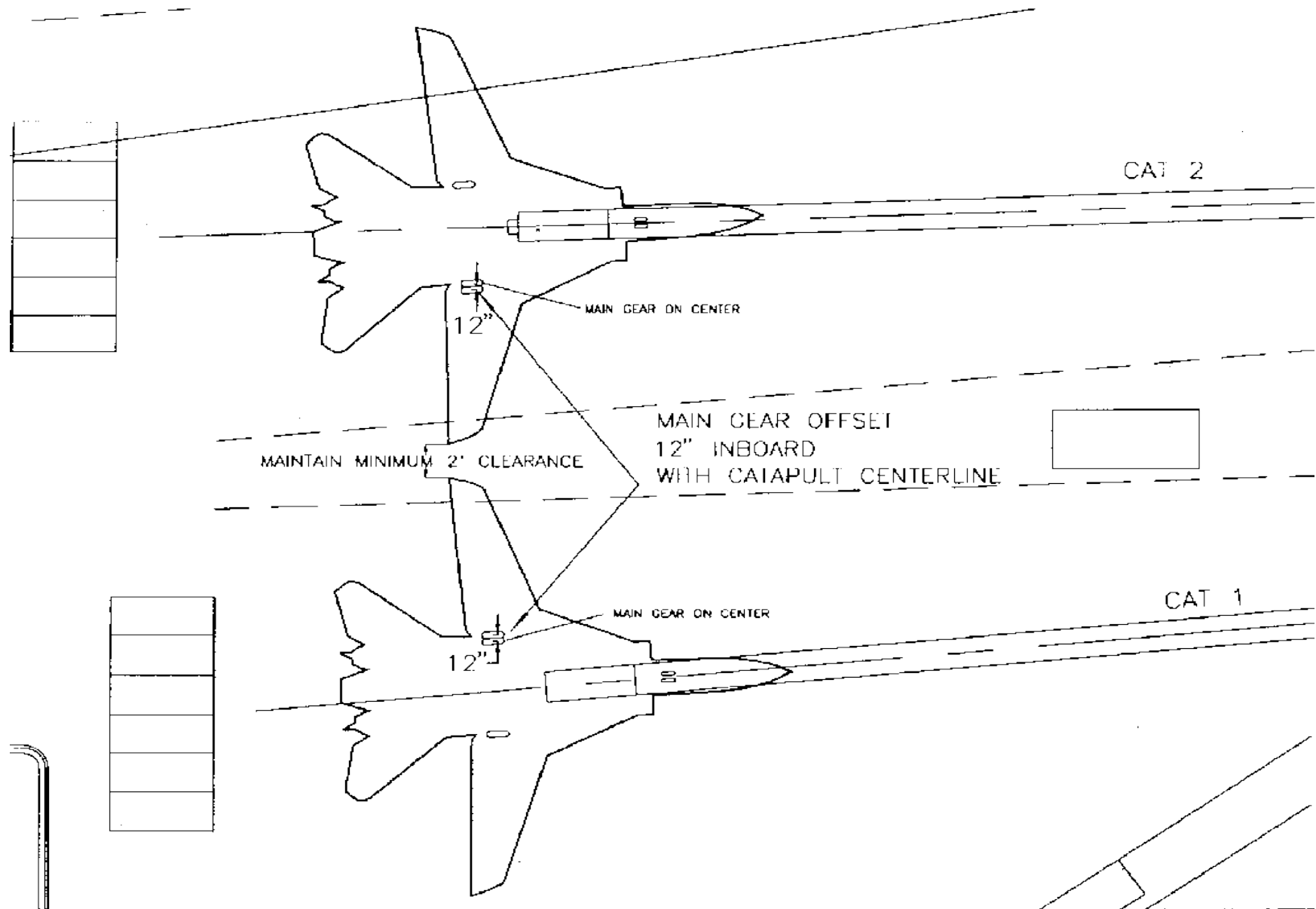


GEOMETRIC COMPATIBILITY FOR LAUNCH

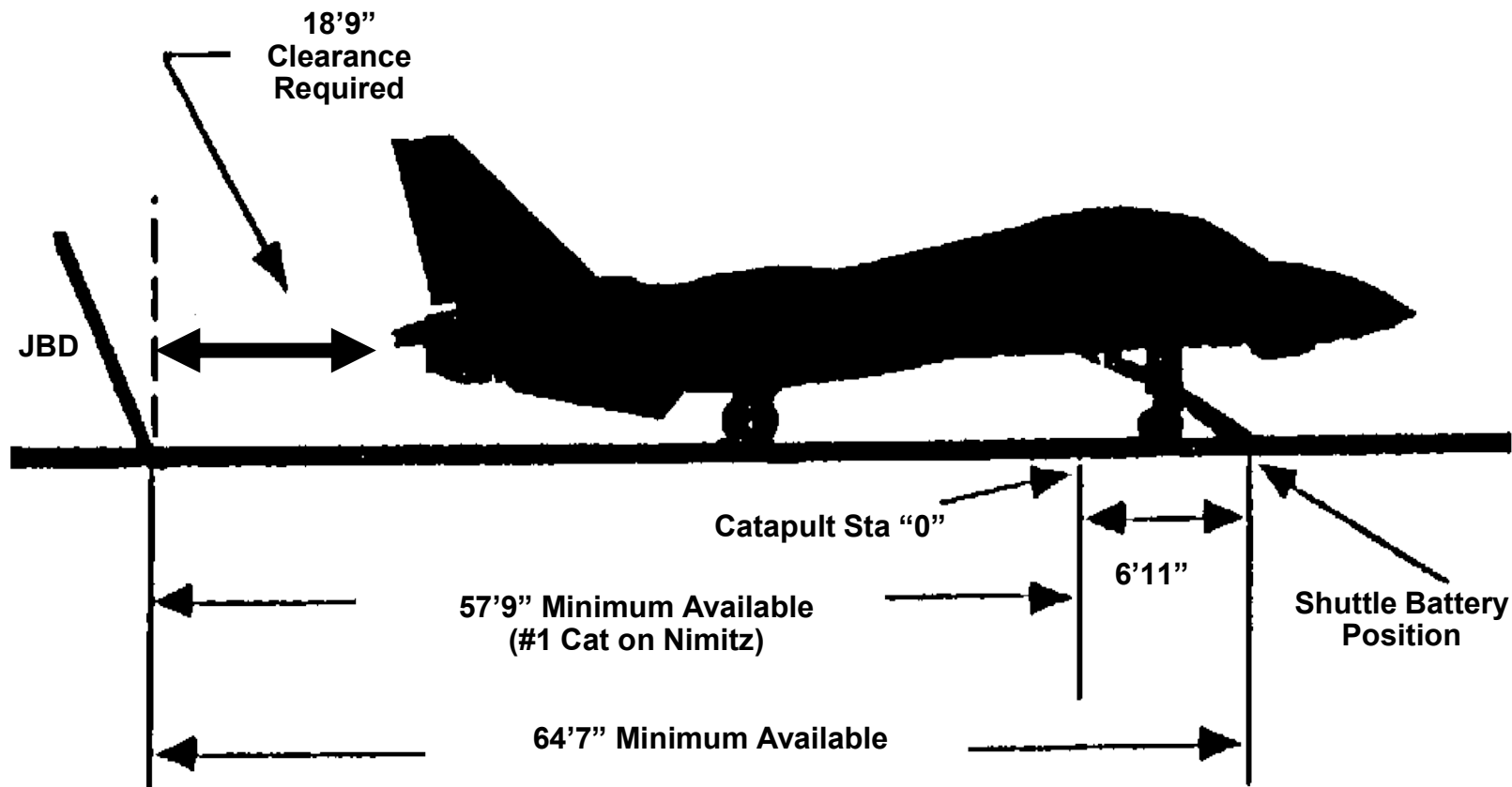
Clearances Required for Launching

- **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**

WINGTIP CLEARANCE



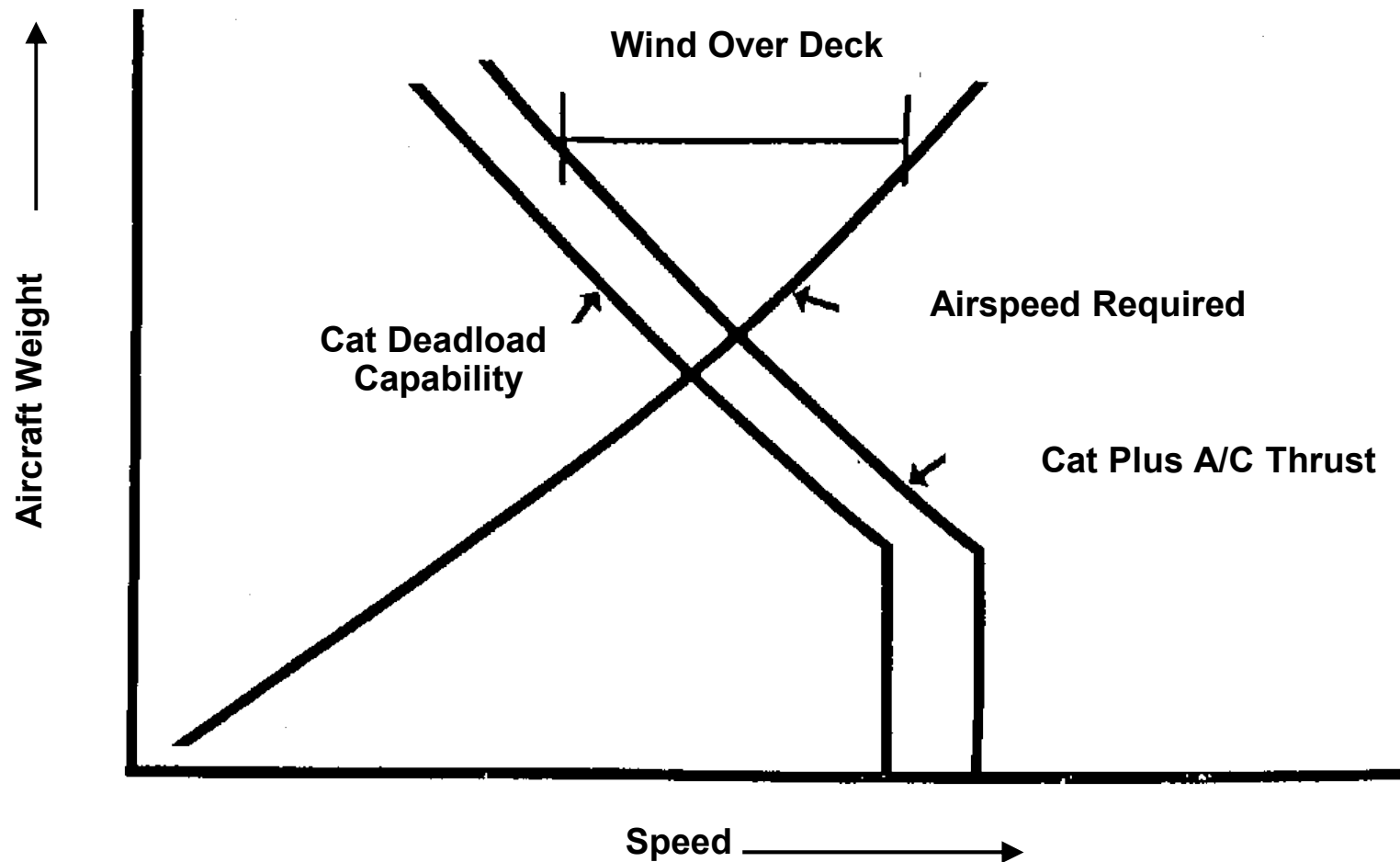
JET BLAST DEFLECTOR (JBD) CLEARANCE



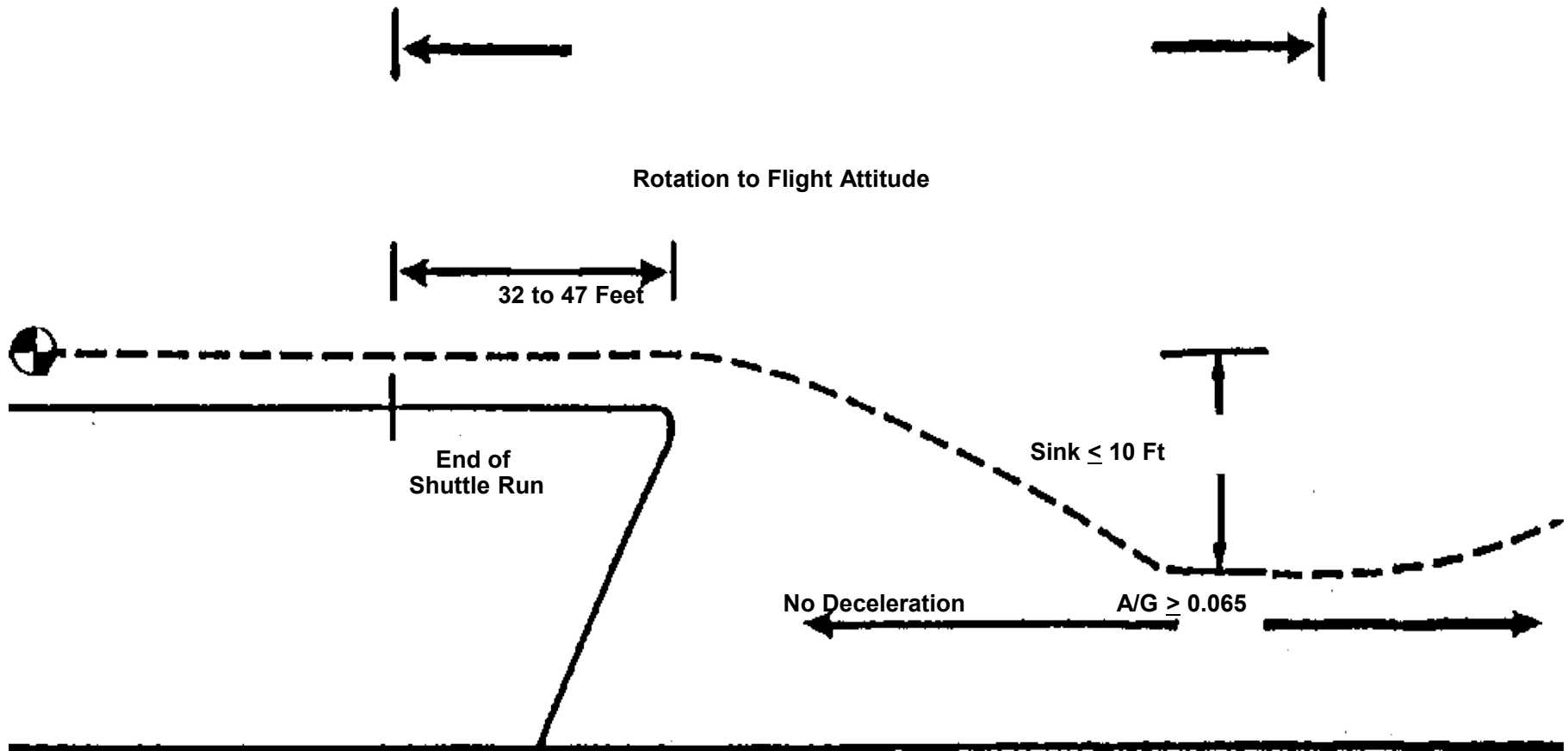
- Aircraft Launch Bar to Tail Distance Constrained By JBD Clearance to 45'40"
 - Typical Aircraft:
- | | |
|----------|-------|
| F-14A- | 45.9' |
| F/A-18A- | 38.6' |
| F/A-18E- | 41.7' |

LAUNCHING

LAUNCH WIND OVER DECK



LAUNCH FLIGHT PATH



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

LAUNCHING



LAUNCHING



LAUNCHING

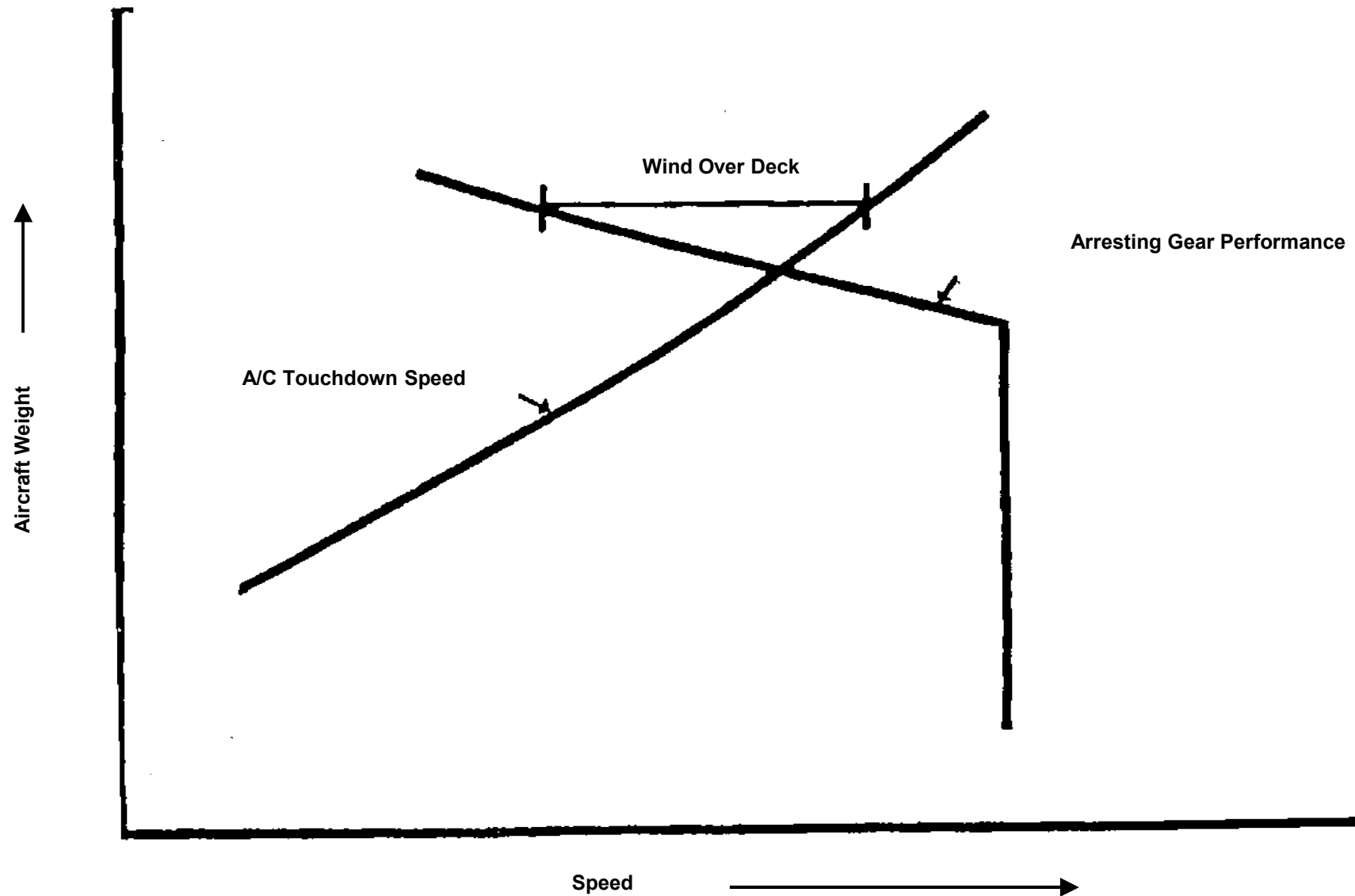


LAUNCHING



RECOVERY

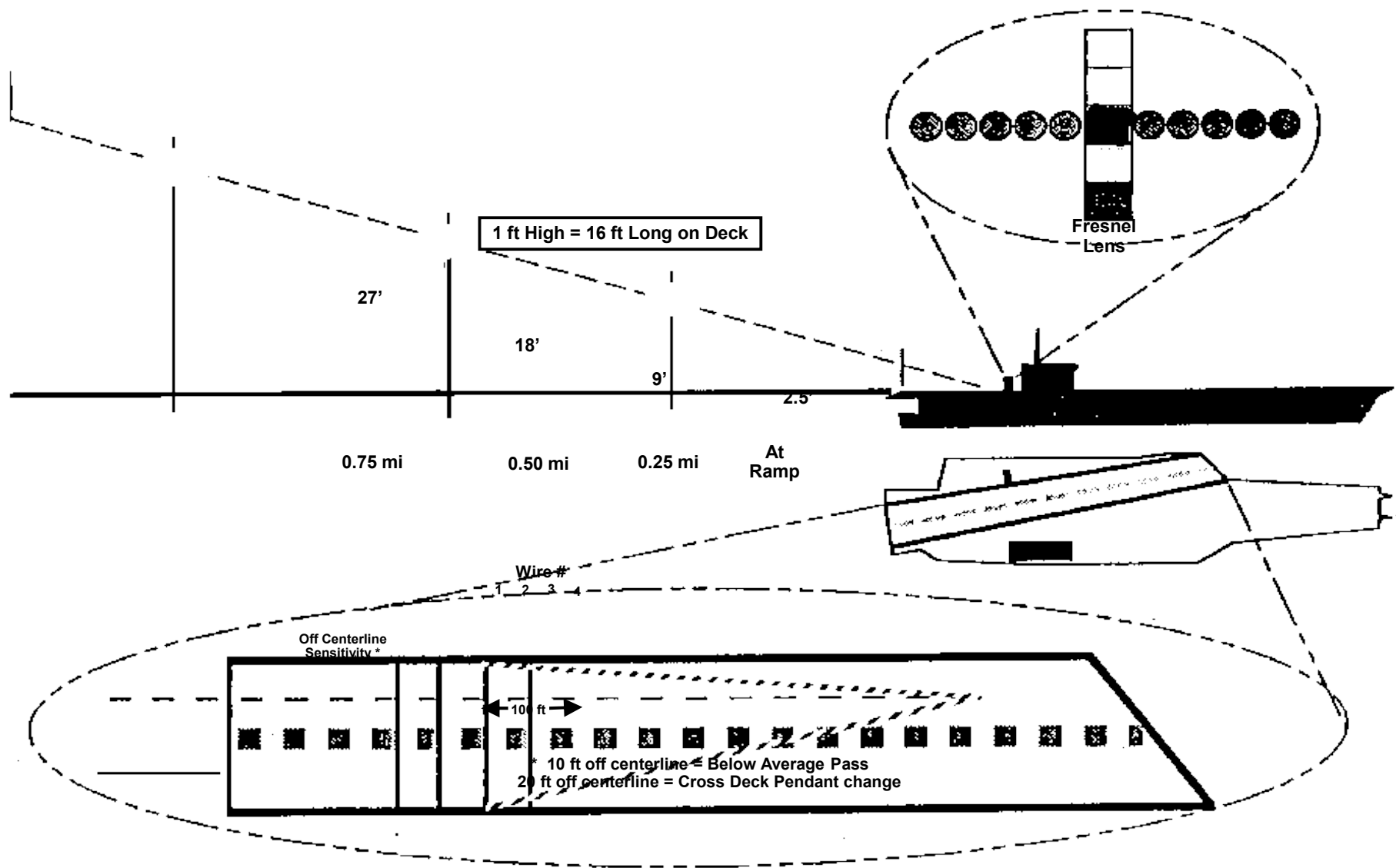
RECOVERY WIND OVER DECK (Recovery Headwind)



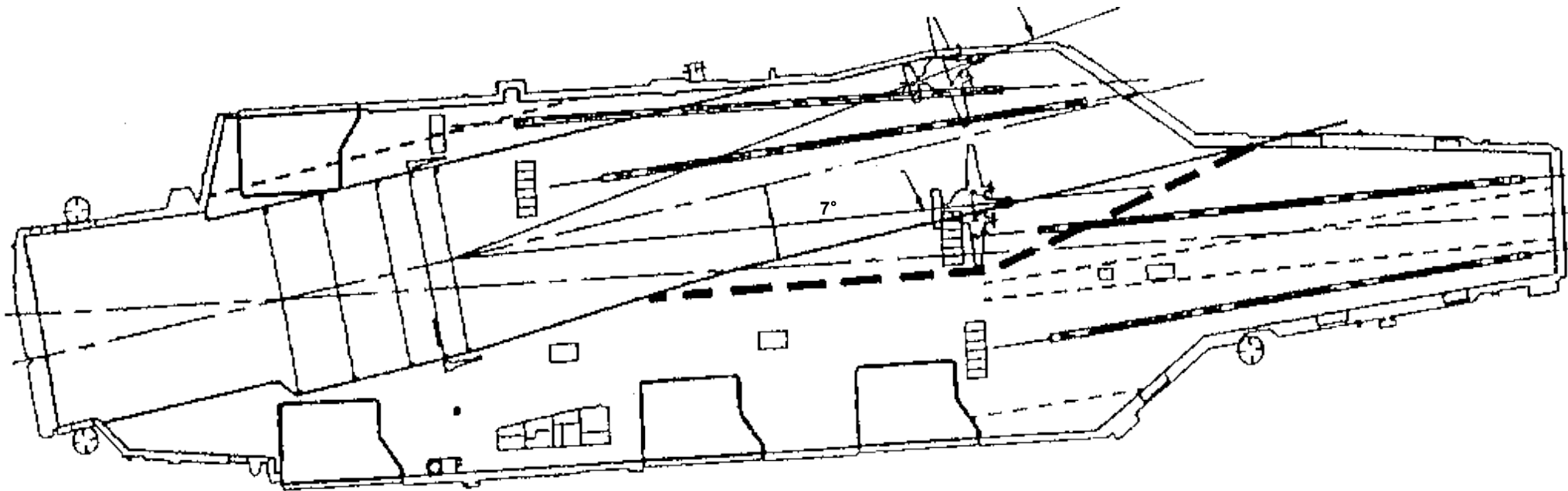
APPROACH SPEED CRITERIA

- 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

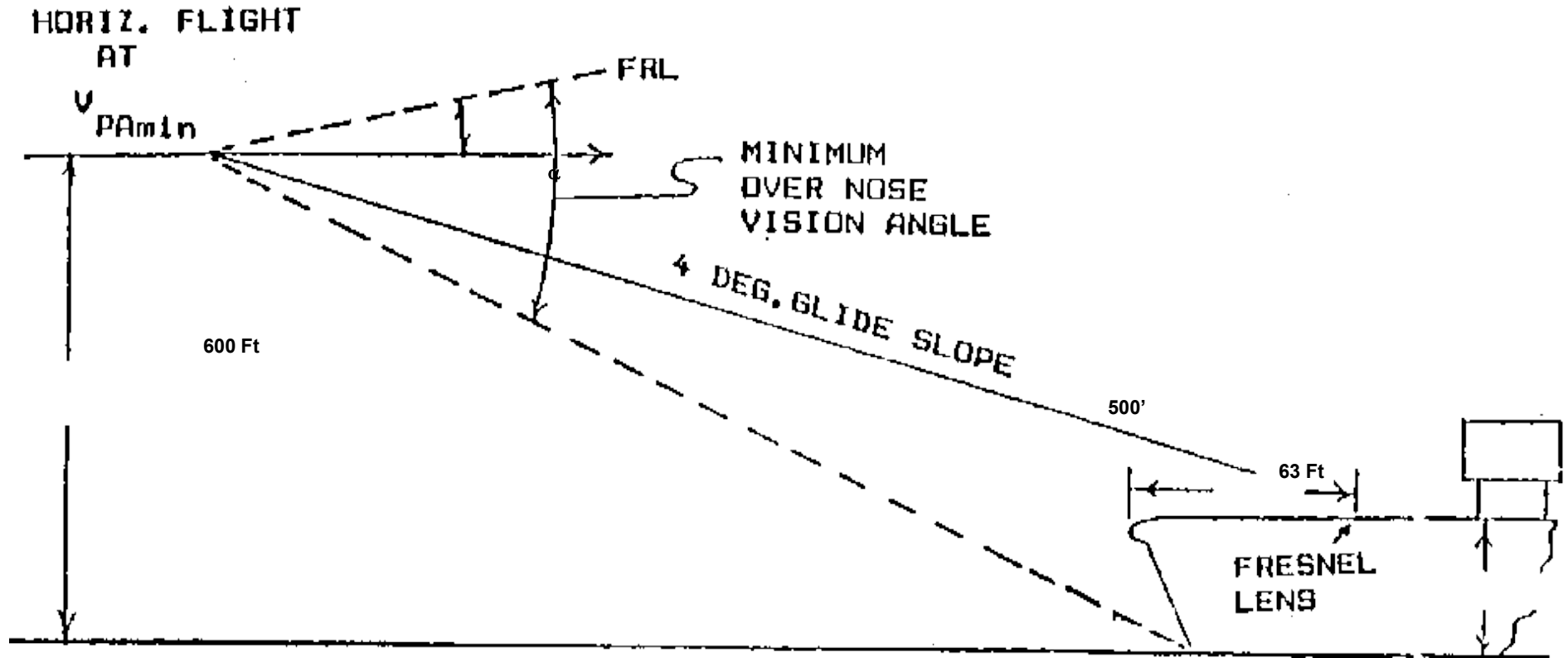
GLIDE SLOPE / LINE-UP CONTROL



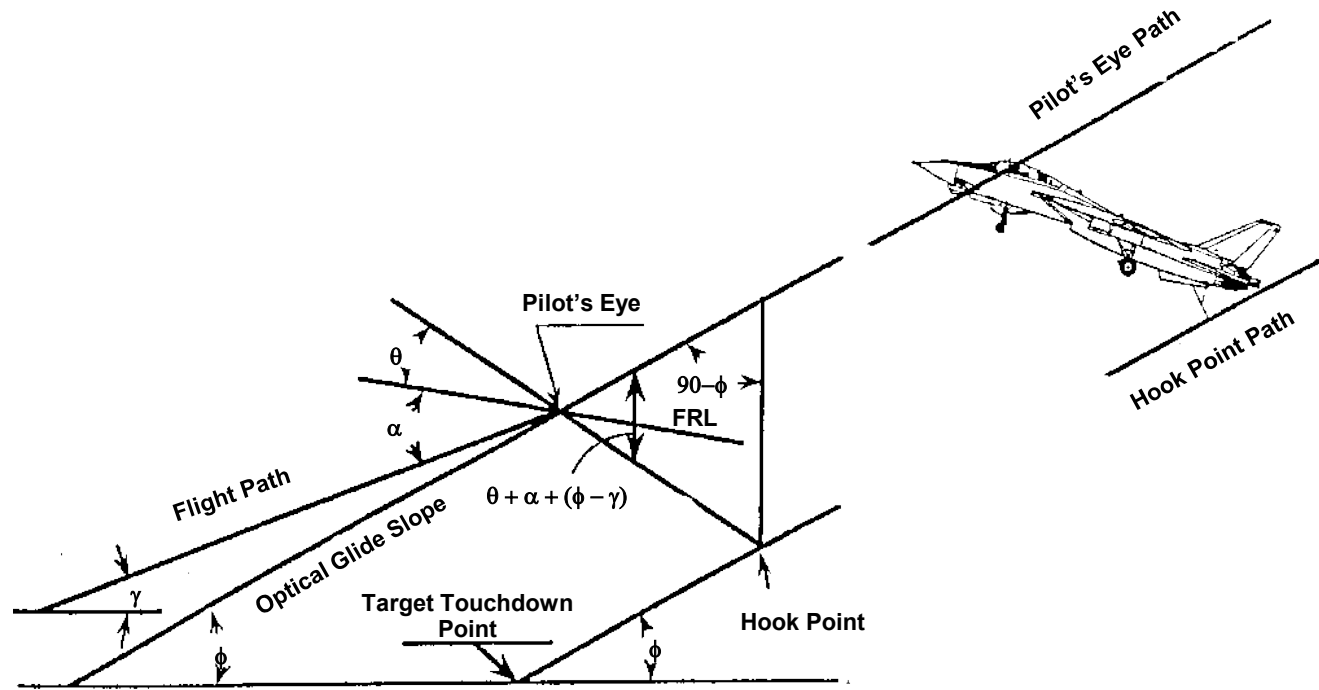
CVN 68
MK7 MOD3 ARRESTING GEAR(345 FT TO TAIL HOOK)
CONVENTIONAL 4 WIRE SYSTEM



CARRIER APPROACH VISION



HOOK-TO-EYE GEOMETRY





CONCLUSION

NAVY CARRIER REQUIREMENTS HAVE PERVASIVE IMPACT ON DESIGN

Design Factors	Carrier Unique Modes of Operation				
	Launch	Recovery	Deck Handling	Maint' & Service	Maritime Environment
Geometric	Major	Major	Major	Moderate	
Aerodynamic	Major	Major			
Structural	Major	Major	Moderate	Slight	Moderate
Unique Equipment	Major	Major	Major		
Cockpit	Moderate	Moderate	Moderate	Slight	Moderate
Fuel System	Moderate	Moderate		Moderate	
Propulsion	Moderate	Moderate	Slight	Moderate	Moderate
Weapon Instl'n	Moderate	Moderate	Moderate	Slight	
Major Subsystems	Moderate	Moderate	Moderate	Major	Moderate

NOTE: IMPACTS CAN BE: WEIGHT, COST, COMPLEXITY, TESTING

Aircraft Carrier - Design Considerations

WING AREA:

Higher to: Increase Lift, Improve Inst. Turn Rate

Lower to: Reduce Empty Wt. and Roll Inertia,
Reduce required Tail Size

WING ASPECT RATIO:

Higher to: Increase Lift at low AOA, Reduce Drag,
Increase available Control Surface Span,
Improve Cruise/Loiter and Sust. Turn Rate

Lower to: Reduce Empty Wt. and Roll Inertia,
Improve Deck Clearances (esp. in rolled att.)
Reduce required Tail Size
Allow side-by-side unfolded on Cats 1&2

TAIL SURFACES:

Larger to: Improve Control Response at CV Speeds
Smaller to: Reduce Empty Wt. and Spotting Factor

Aircraft Carrier - Design Considerations (Continued)

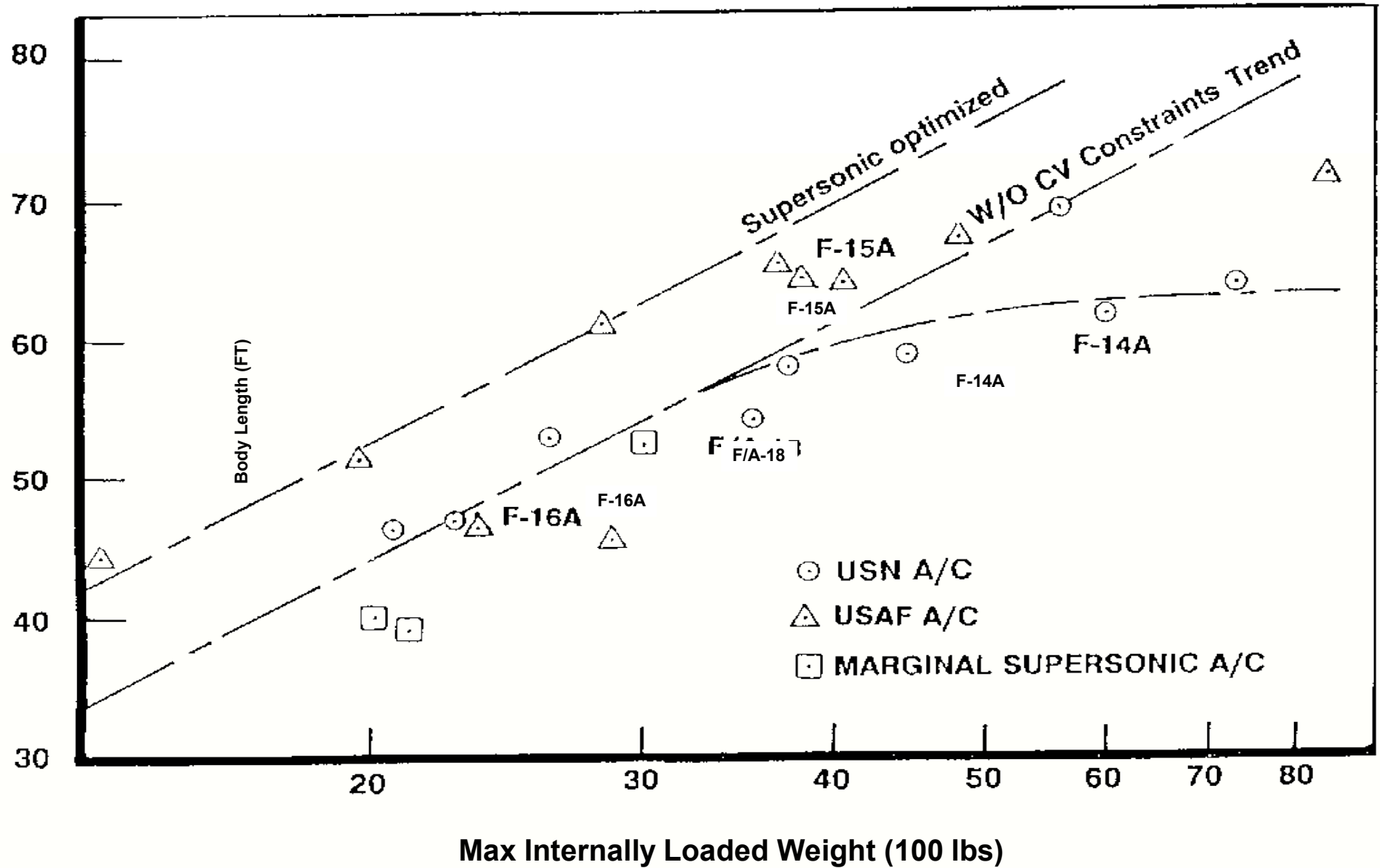
FUSELAGE LENGTH:

**Longer to: Improve Tail Moment Arms,
Provide “real estate” to integrate propulsion, crew,
structure, weapons, and systems
Improve Supersonic capability**

**Shorter to: Reduce Empty Wt.,
Reduce pitch and yaw Inertias,
Reduce Spotting Factor
Improve Deck Clearance in Tail-down Attitudes
Improve JBD Clearance**

Max Practical Length approx. 62 feet

TRENDS IN LENGTH OF TACTICAL AIRCRAFT



LANDING GEAR:

**Longer to: Improve Accessibility
Improve Deck Clearances Tail-down or Rolled**

**Shorter to: Reduce Empty Wt.
Resist Roll-over**

Aft to: Resist Tip-back

Forward to: Improve Bolter

**Outboard to: Resist Roll-over (but not to exceed
11 feet from Center Line)**

Rx FOR A GOOD CARRIER AIRCRAFT

1. Restraint in Requirements Setting Process
2. Set Geometry for CV Compatibility at the Start
3. Minimize Weight Empty
4. Design for Low WOD Launch & Arrest at Realistic Loads
5. Pay Attention to Fundamental Low Speed Stability & Control
6. Ample Control Power
7. Responsive Engine
8. Use Materials and Practices Compatible with High Stress, Humid, Corrosive, Dense EM Environment