

Electric Machine Stops Aircraft in its Tracks

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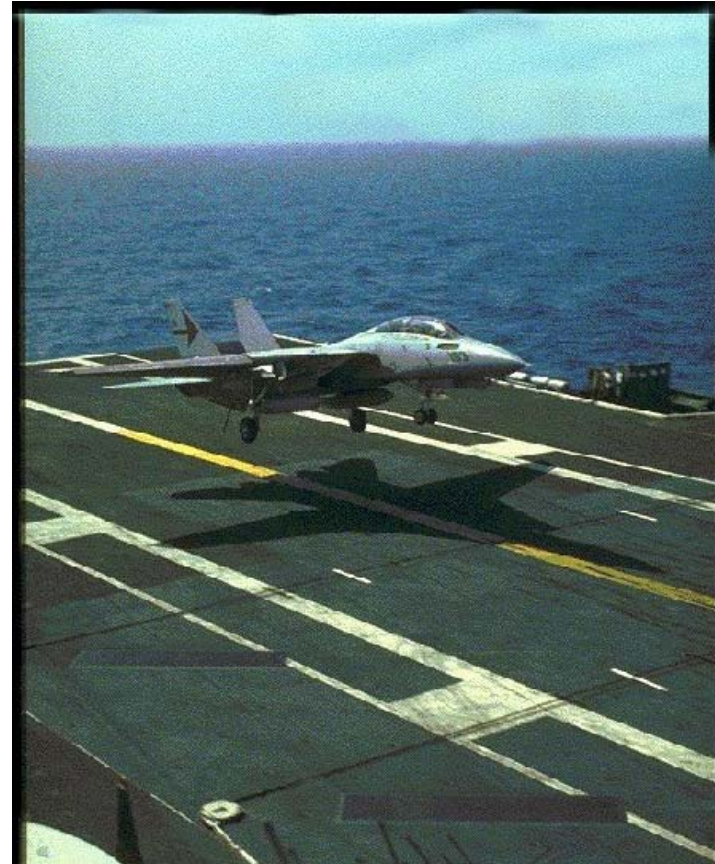
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Electric Aircraft Arrestors

- Revolutionary aircraft recovery system
- Linear electric motors below the flight deck
- Cables connect the motor to the aircraft
- Total machine rating: 109 MJ (80 million foot-pounds)



Electric Machines for Aircraft Arrestor

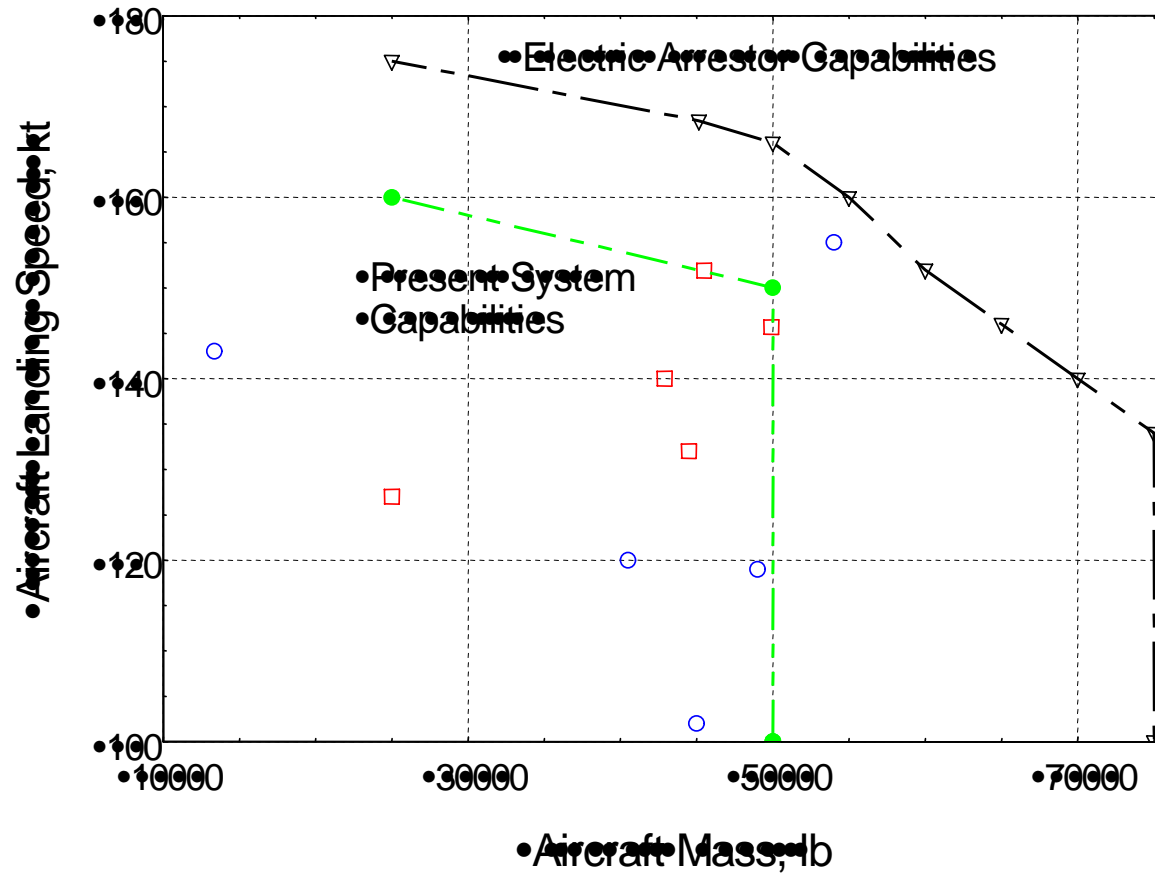
- Increased performance
 - Greater arriving aircraft energy, speed and mass
 - Reduced peak-to-mean force ratio on aircraft
 - Reduced maintenance
 - Low maintenance electric motor
 - Self-diagnostics
 - Reduced system mass & volume
 - Single stator per 2 cross-deck pendants
-

Navy Needs:

ALM Arrestor Attributes - 1

Navy Needs	ALM Arrestor Attributes	ALM Functions/Features
<i>Survivability:</i>	Rapid aircraft cycle time	Intelligent automated control of arrestor operation: rapid shuttle return and real time individual adjustment
	“Dark ship” recovery operations	Integral energy storage
<i>Sustainability:</i>	Lower manning	Automated operations
	Lower maintenance	Self-diagnostic controls, redundant power electronics, simplified motor.
	Higher reliability	Graceful degradation through redundancy and simplicity
<i>Mobility:</i>	Reduced WOD requirements	Increased energy capability
	Reduced system weight and volume	Single stator, dual shuttles; Two trap wires per single stator

Arrestor Capabilities & Aircraft Requirements



Navy Needs:

ALM Arrestor Attributes - 2

Navy Needs	ALM Arrestor Attributes	ALM Functions/Features
<i>Affordability:</i>	Reduced runout	Efficient deck usage; Higher energy capability
	Reduced airframe stresses	Controlled arrest profile
	Reduced peak-to-mean force	Closed-loop control
	Eliminate hazardous materials	Hydraulic oil not used
<i>Design Flexibility:</i>	Single stator arrestor	Dual shuttles on single stator Reduced parts count
	Installation flexibility	4:1 purchase ratio allows athwartship installation
<i>Performance:</i>	Reduced airframe stress Reduced runout	High bandwidth force control Advanced high level control

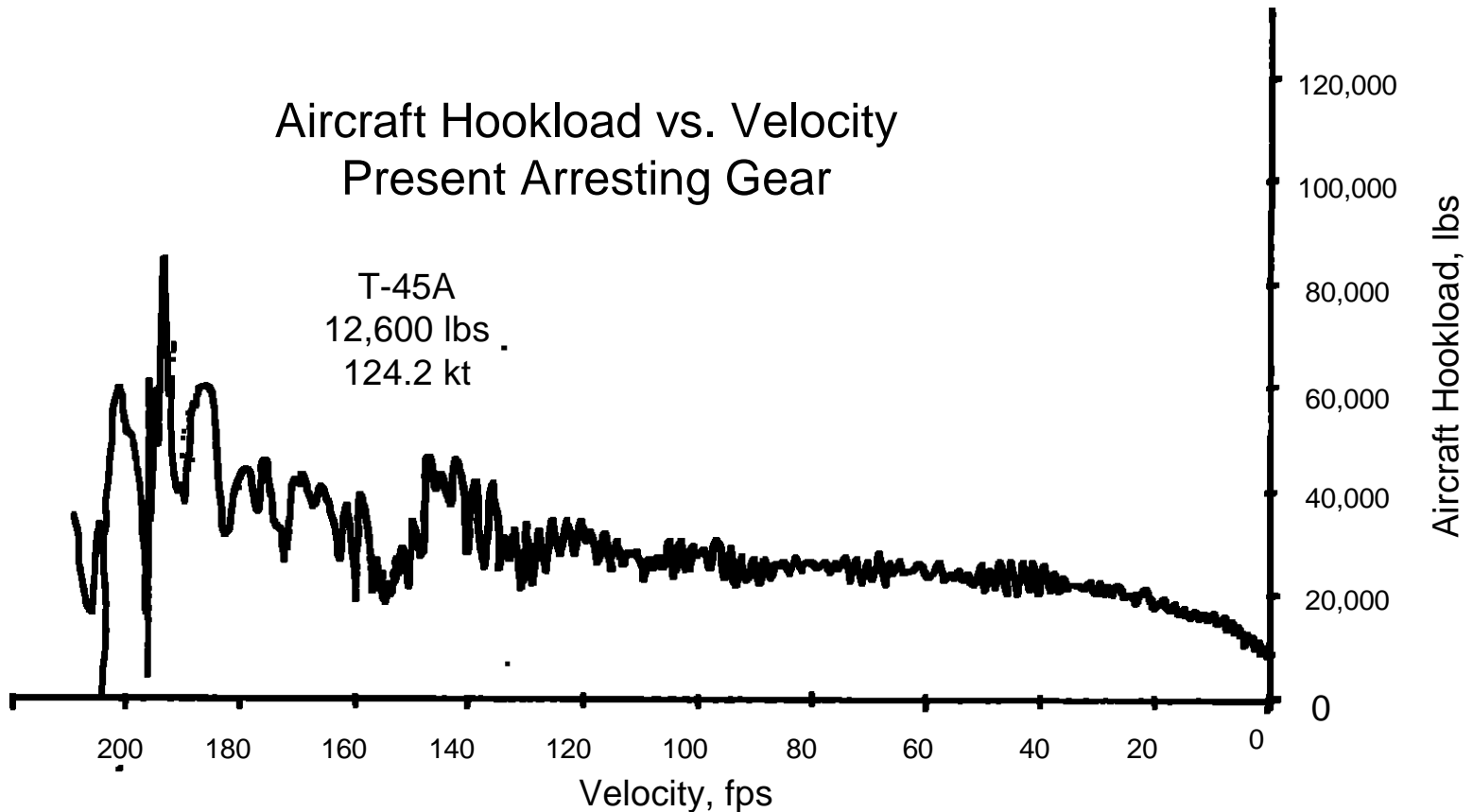
John C. Stennis First Trap

(note the cable-whip)



Large Peak-to-Mean Ratio of Aircraft Hookload

Aircraft Hookload vs. Velocity
Present Arresting Gear



Navy Lakehurst BAA 802

Advanced Linear Motor

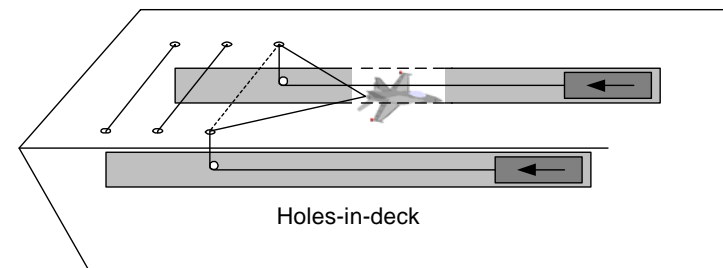
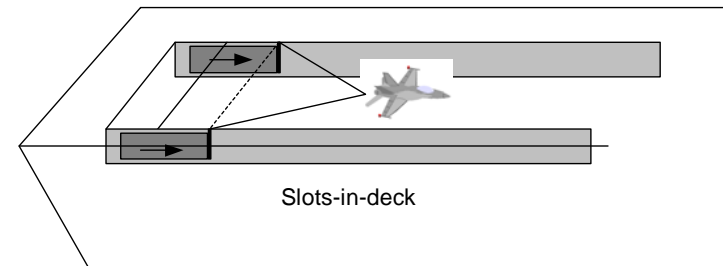
- Government sez:
 - Planned \$14.5M over 3 years
 - Funding depends upon ATD ranking: #3 or #4
 - Funding may be determined in November
 - *Nobody* (yet) chosen as Prime Contractor
- Industry sez:
 - \$15M and more req'd
 - 14 Proposals received
 - Credibility for Navy arrestor/launcher applications depends upon funding
 - XX selected for negotiations

Navy Lakehurst BAA 802 Advanced Linear Motor

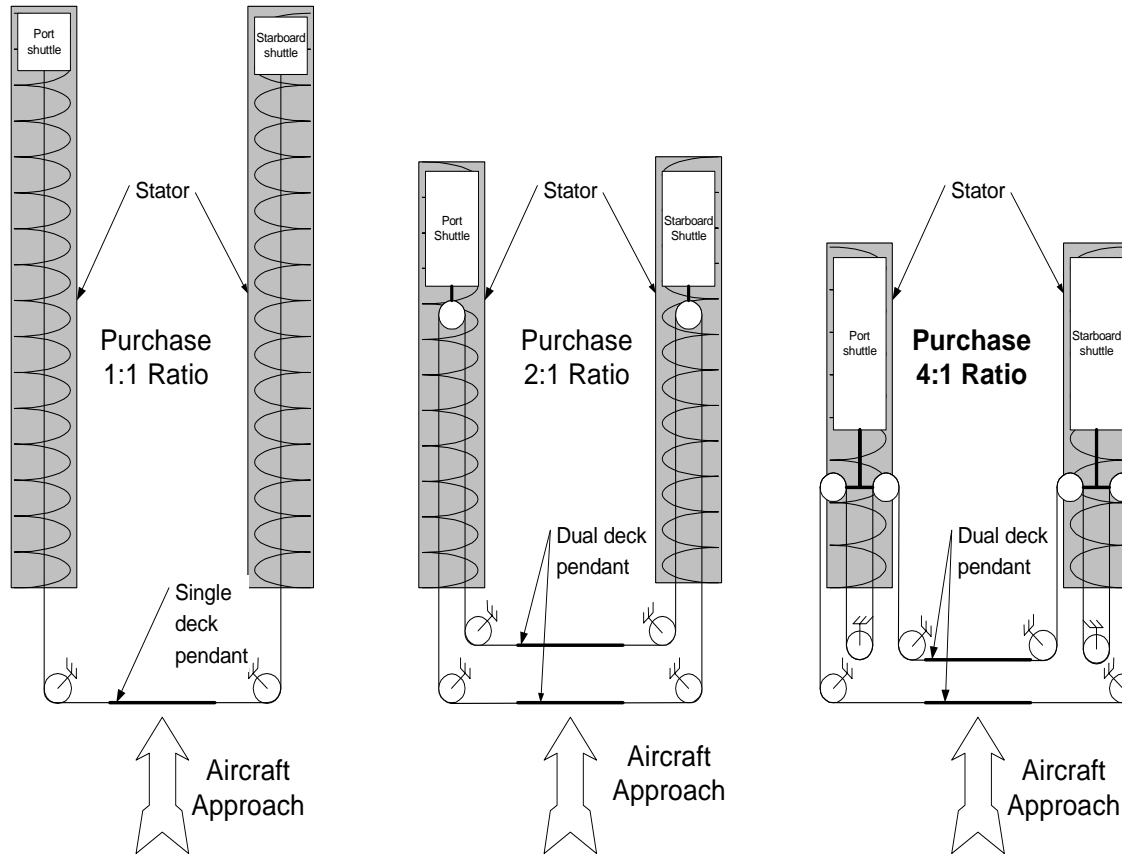
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Two Fundamental Arrestor Configurations

- Slot-in-deck:
 - Shuttle pulled askew
 - FOD, reliability are concerns
 - Slot length = runout *plus* shuttle length
- Hole-in-deck:
 - Shuttle pulled straight
 - Covered pass-throughs
 - Sheaves can provide Purchase Ratio

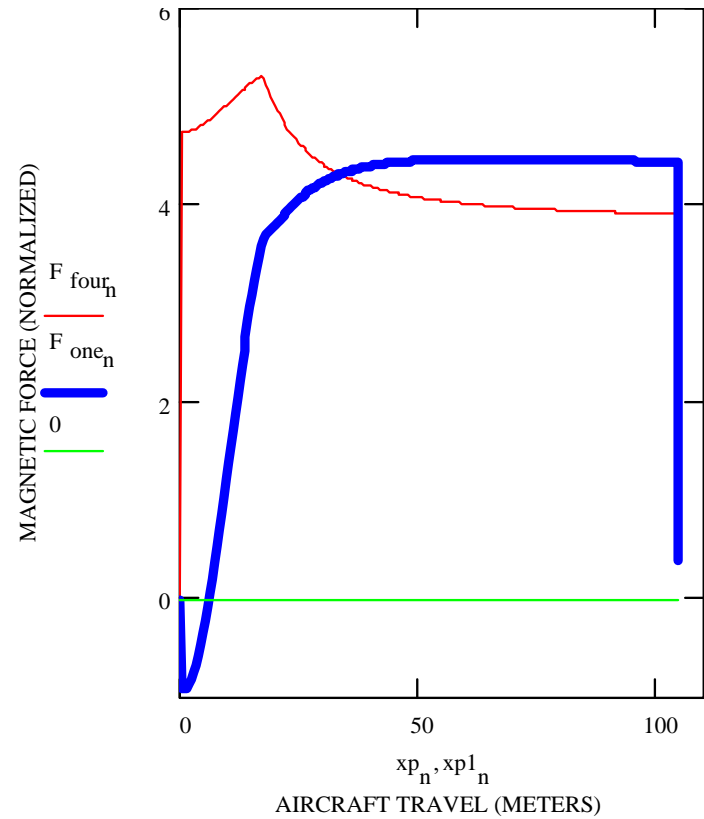


Arrestor Configuration: Purchase Ratio Layouts



Motor Force Requirements vs. Purchase Ratio

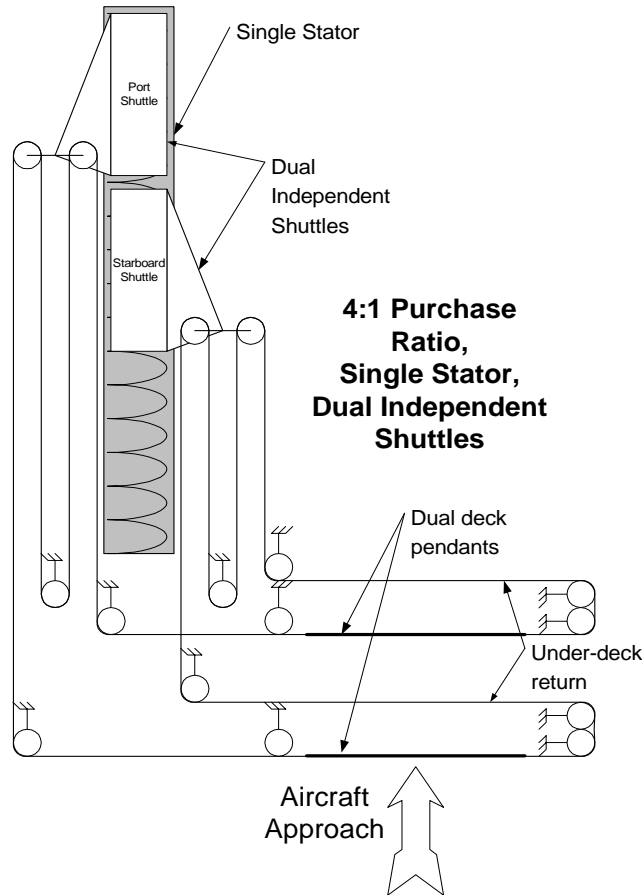
- Two NTE limitations:
 - Aircraft hookload
 - Cable tension
- Purchase Ratio of 1:1 requires arrestor *acceleration*
- Purchase Ratio of 4:1 minimizes arrestor cost & complexity



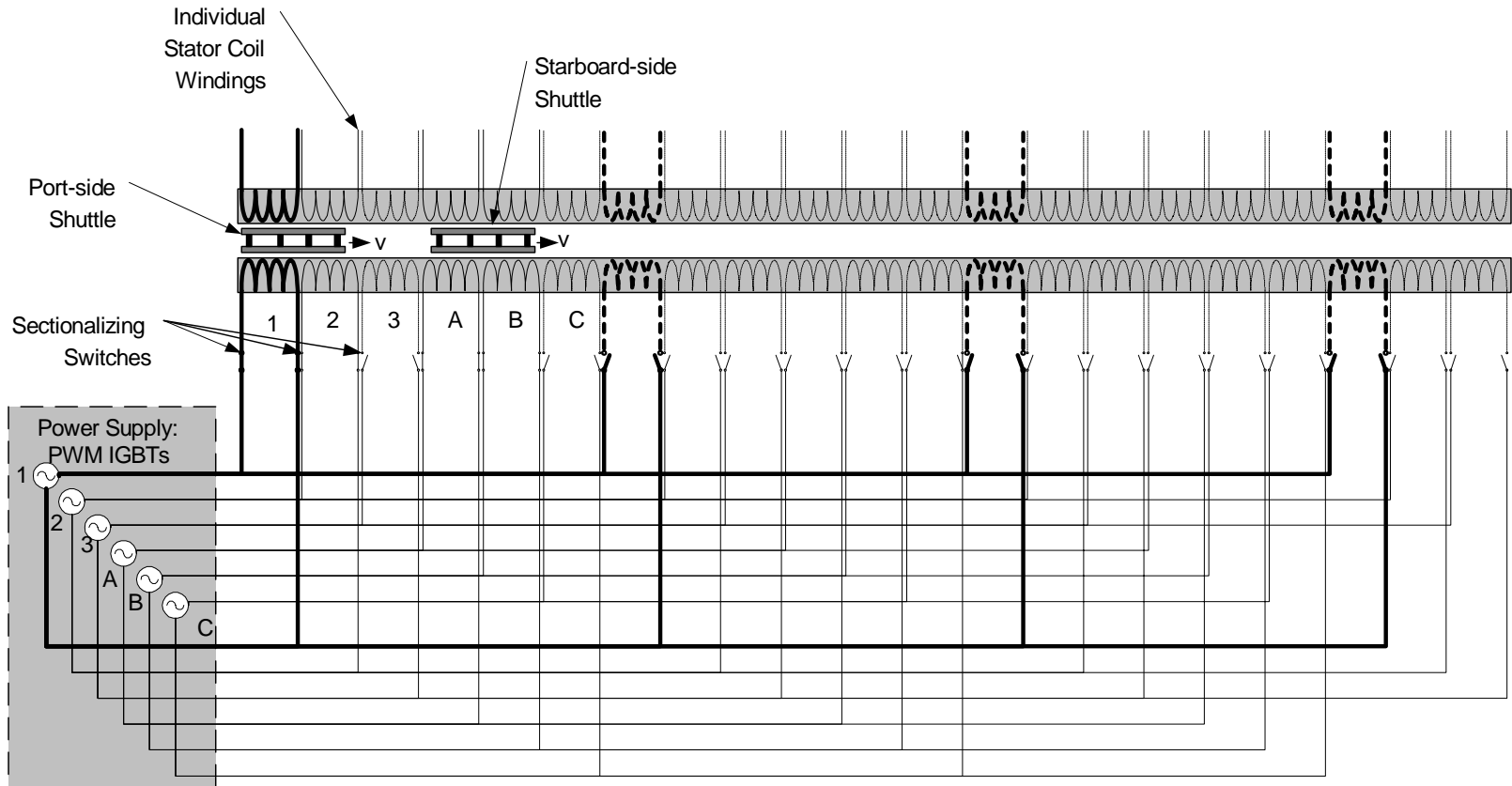
Engineering Matters' *Arrestor System Design*

- Induction machine (generator and motor)
 - Purchase ratio 4:1, stators installed athwartship or longitudinally
 - Many-phase, short-block power electronic architecture
 - Flywheel energy storage for “dark ship” operations
 - Advanced controls
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Selected Arrestor Configuration: Single Stator w/ Independent Shuttles

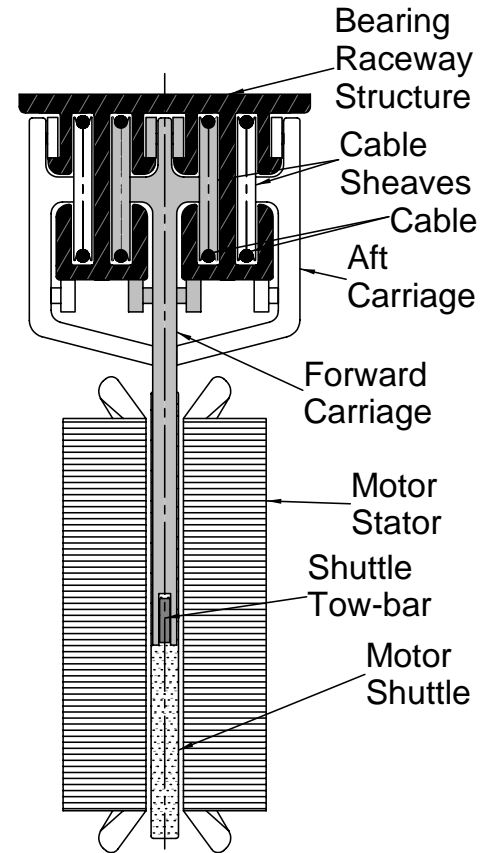


Many-phase short block power electronic architecture

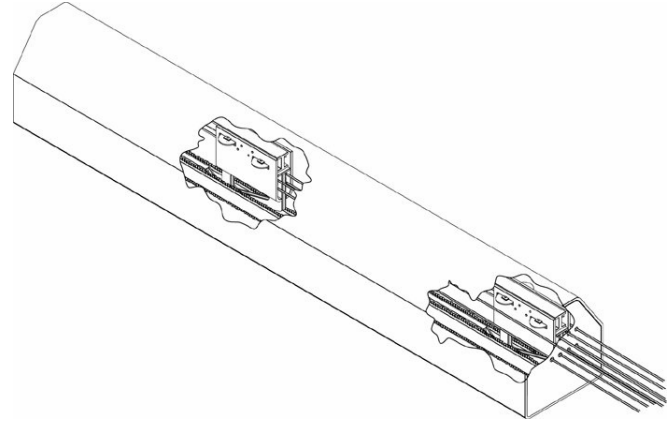
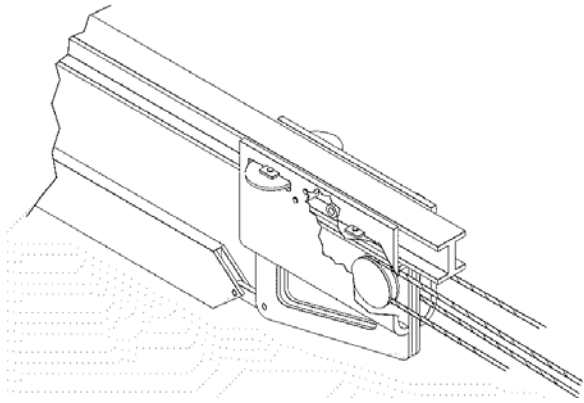
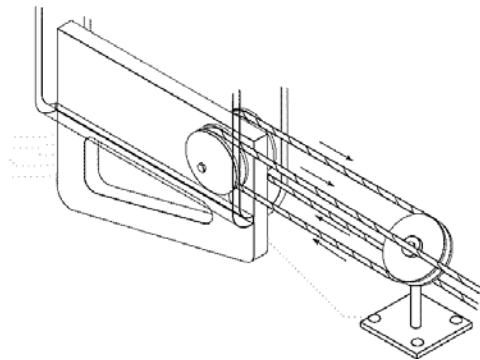
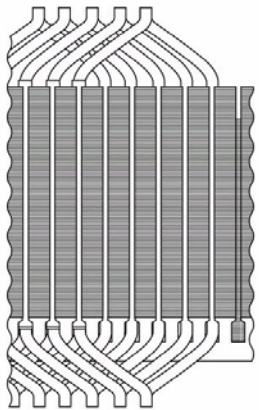


Engineering Matters' *Linear Motor Design*

- Single stator, dual shuttle, double-sided, long stator, 4:1 purchase ratio
- Combined dynamic braking and energy regeneration
- Low mass iron-less shuttles



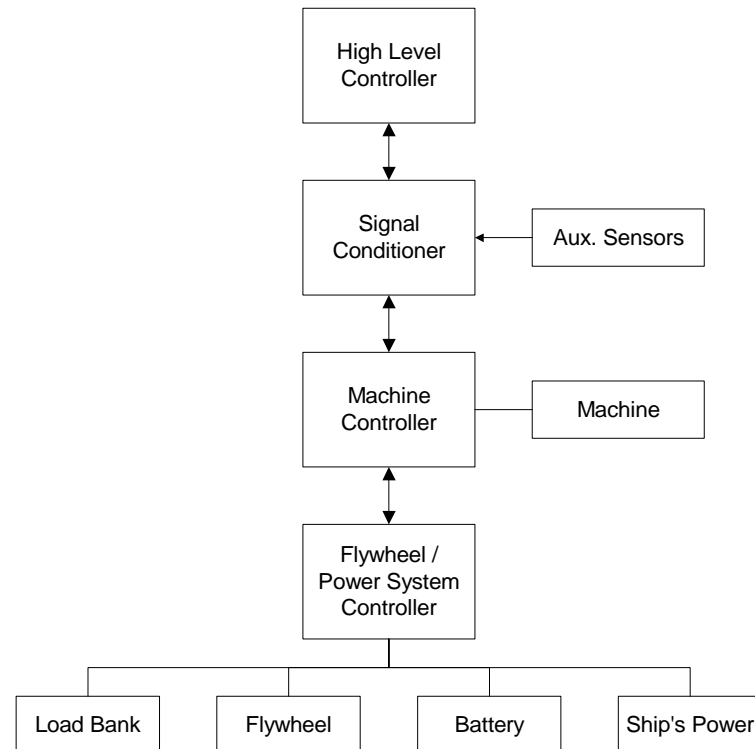
Linear Induction Machine Components



Engineering Matters' Controls Architecture

- Advanced high level system controls
- Low level induction motor and energy storage controls
- Self-diagnostic

Conceptual Control System



Electric Arrestor Summary

- An Electric Aircraft Arrestor provides many advantages (performance, manning, maintenance, reliability, reduced mass, etc.)
 - The Navy is (actively) pursuing this option
 - Innovative and intelligent applications of well-known technology make a better system design
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Electric Machine Types

Advantages and Disadvantages

Machine Type	Advantages	Disadvantages
Induction Machine	<ul style="list-style-type: none"> • Rugged • Low maintenance 	<ul style="list-style-type: none"> • High reactive power (with traditional electronics)
Reluctance	<ul style="list-style-type: none"> • Rugged • Low maintenance 	<ul style="list-style-type: none"> • High reactive power • Complicated power electronics • High acoustic noise
Synchronous Permanent Magnet	<ul style="list-style-type: none"> • No field excitation necessary • Low reactive power 	<ul style="list-style-type: none"> • Permanent field (field always ON) • Lower shear force capability • Environmental sensitivity of pm materials
Synchronous Xfrmr-coupled	<ul style="list-style-type: none"> • Low reactive power • Controllable BEMF 	<ul style="list-style-type: none"> • Very heavy rotor • Fragile electronics on rotor
Synchronous Superconducting	<ul style="list-style-type: none"> • Low reactive power • High field 	<ul style="list-style-type: none"> • Unproven availability • High maintenance
Eddy Current Brake	<ul style="list-style-type: none"> • Simple • Rugged 	<ul style="list-style-type: none"> • Unable to retract shuttle • No energy generation • Cannot bring aircraft to complete stop