Versatile Affordable Advance Turbine Engine (VAATE)

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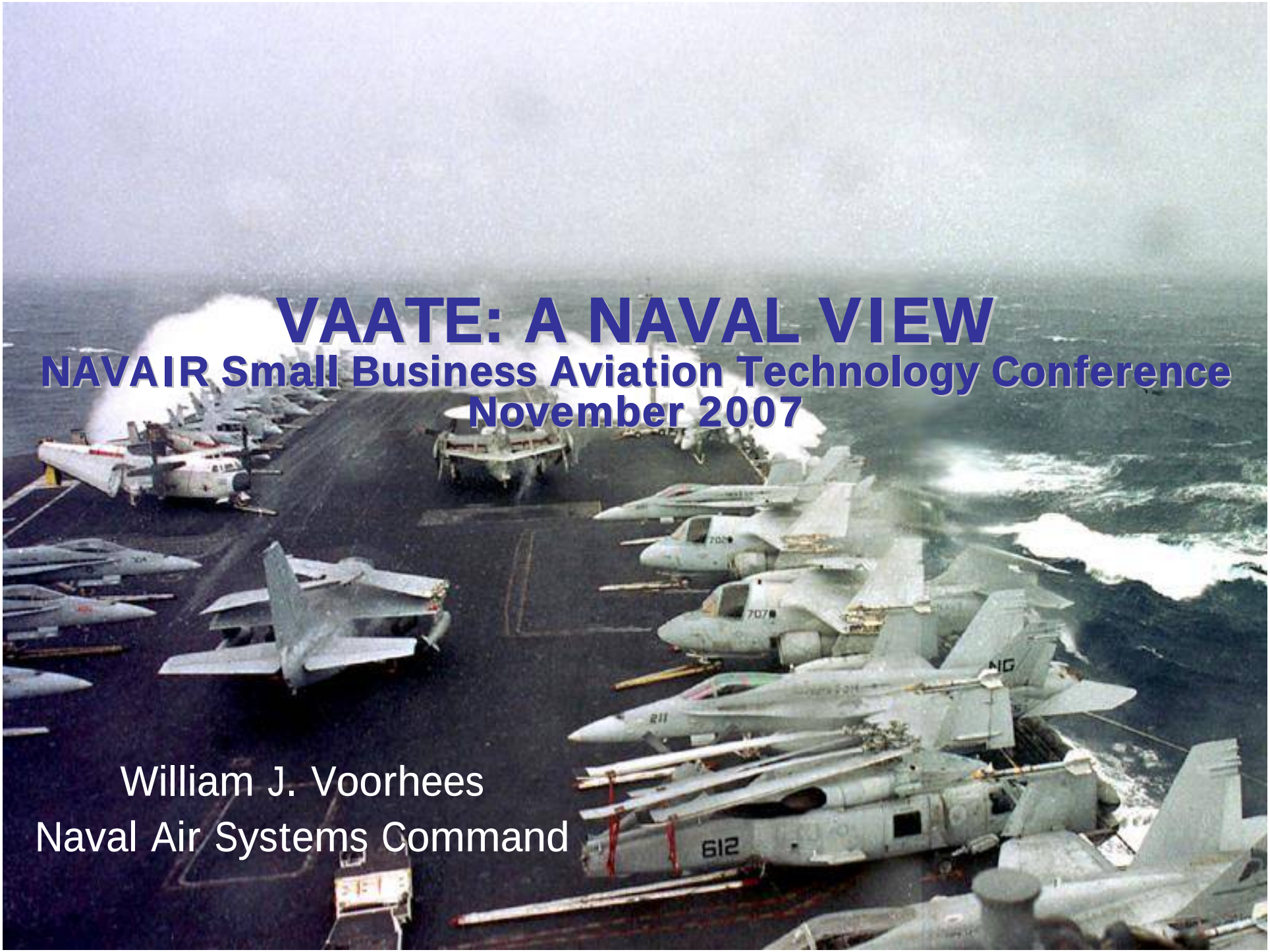


VAATE: A NAVAL VIEW

NAVAIR Small Business Aviation Technology Conference
November 2007

William J. Voorhees
Naval Air Systems Command

Naval Propulsion Technology Investment Guidance

Comes from many sources…

DOD/DDR&E: Defense Planning Guidance, Defense Technology Objectives

CNO/CMC: Naval Power 21, Sea Power 21

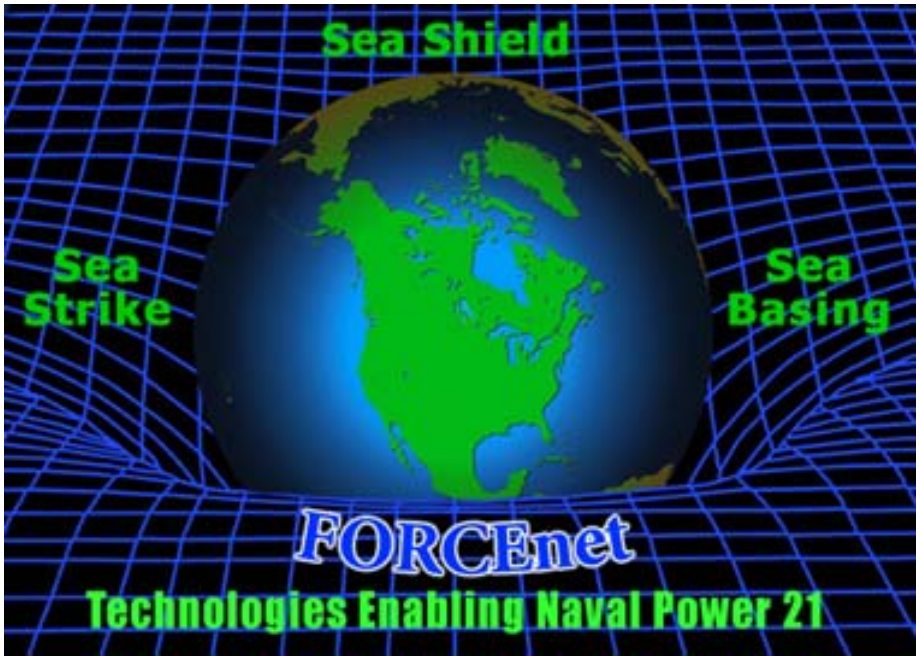
ONR: Naval S&T Strategic Plan, Naval S&T Focus Areas

NAVAL AVIATION ENTERPRISE: NAE S&T Strategic Plan, Prioritized Science & Technology Objectives

PEOs/PMs: Platform Priorities, Capability & Readiness

Fleet: Service-Revealed Deficiencies

. . . etc.



The Naval Vision: Sea Power 21

Sea Shield

- Sea/littoral superiority
- Theater air missile defense
- Force entry enabling

FORCENet

- Enhanced naval, joint & combined operations
- Improved combat effectiveness & mission accomplishment

FORCENet

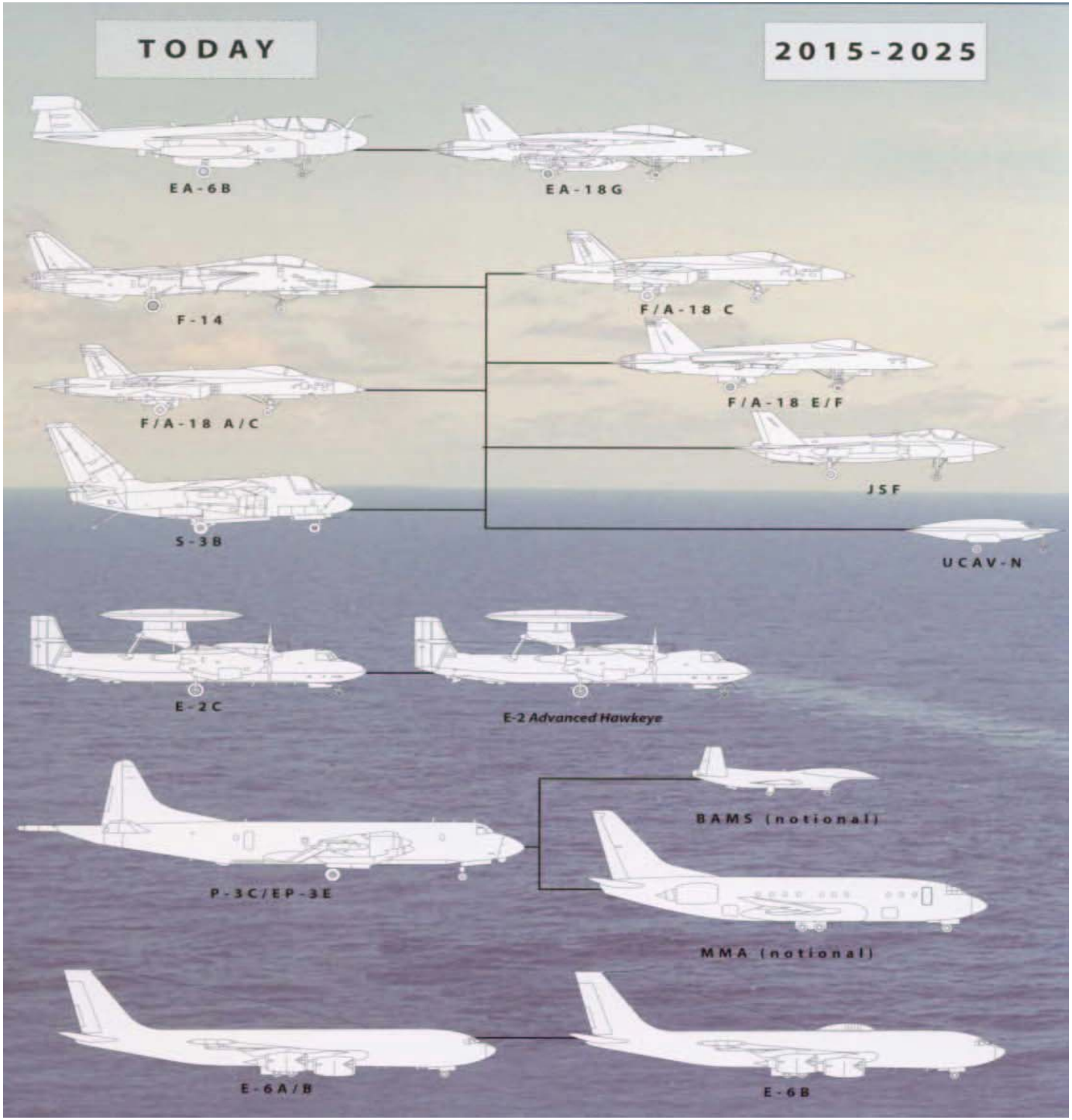
Sea Strike

- Persistent intelligence, surveillance & reconnaissance
- Time-sensitive strike
- Electronic warfare/information operations
- Ship-to-objective maneuver
- Covert strike

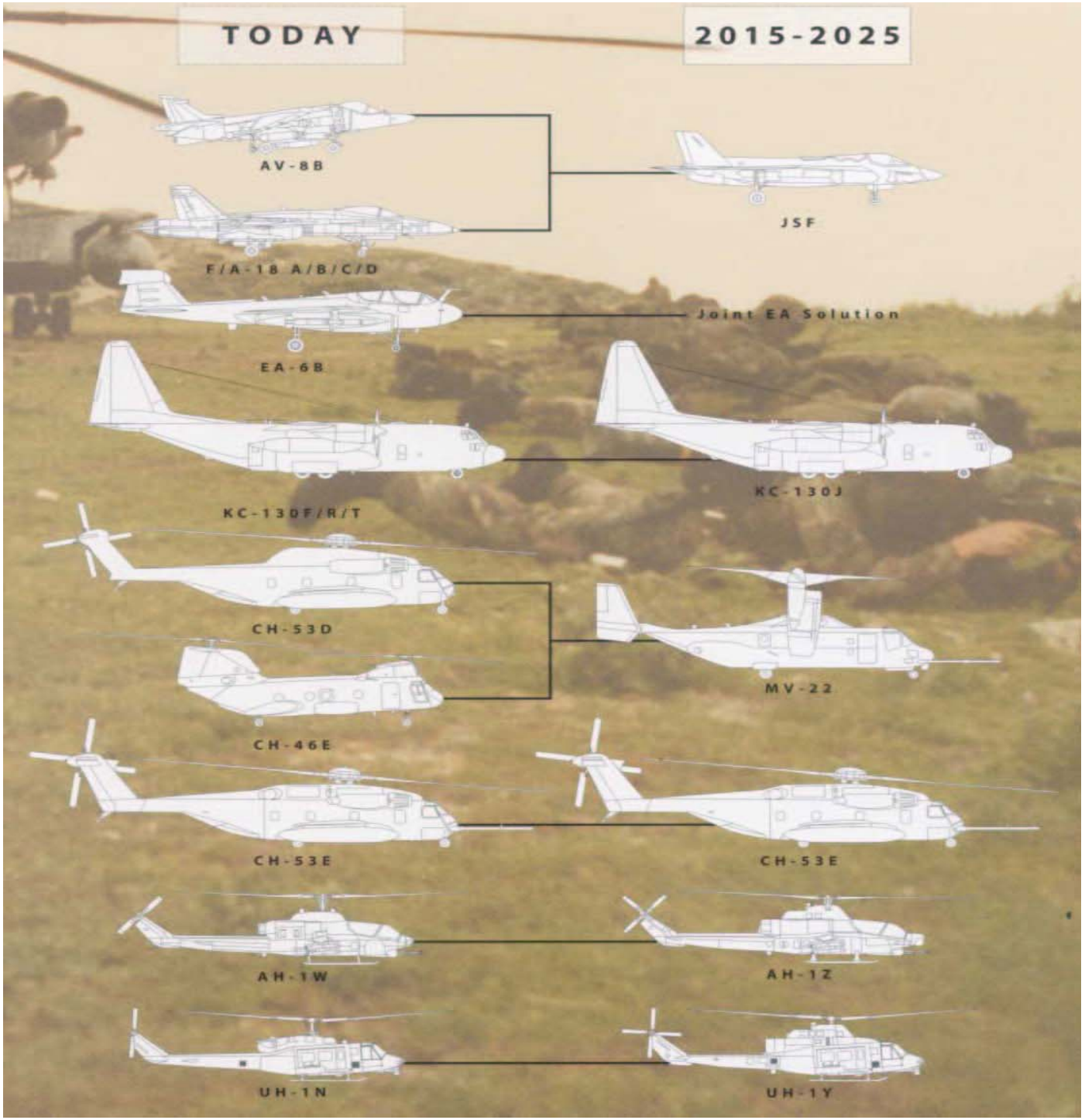
Sea Basing

- Enhanced afloat positioning of joint assets
- Offensive & defensive power projection
- Command & control
- Integrated joint logistics
- Accelerated deployment & employment timelines

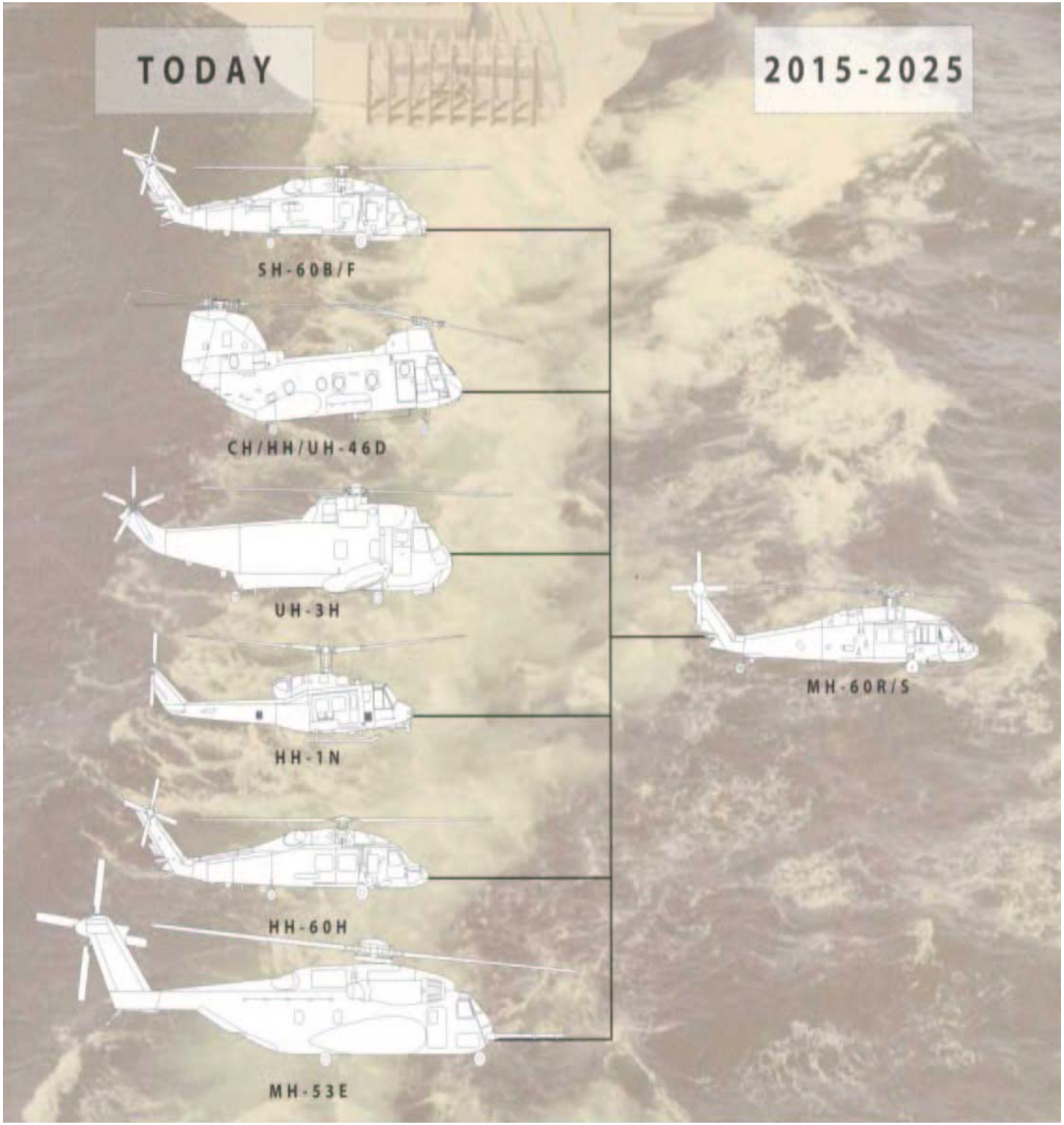
Naval Aviation Touches ALL FOUR PILLARs



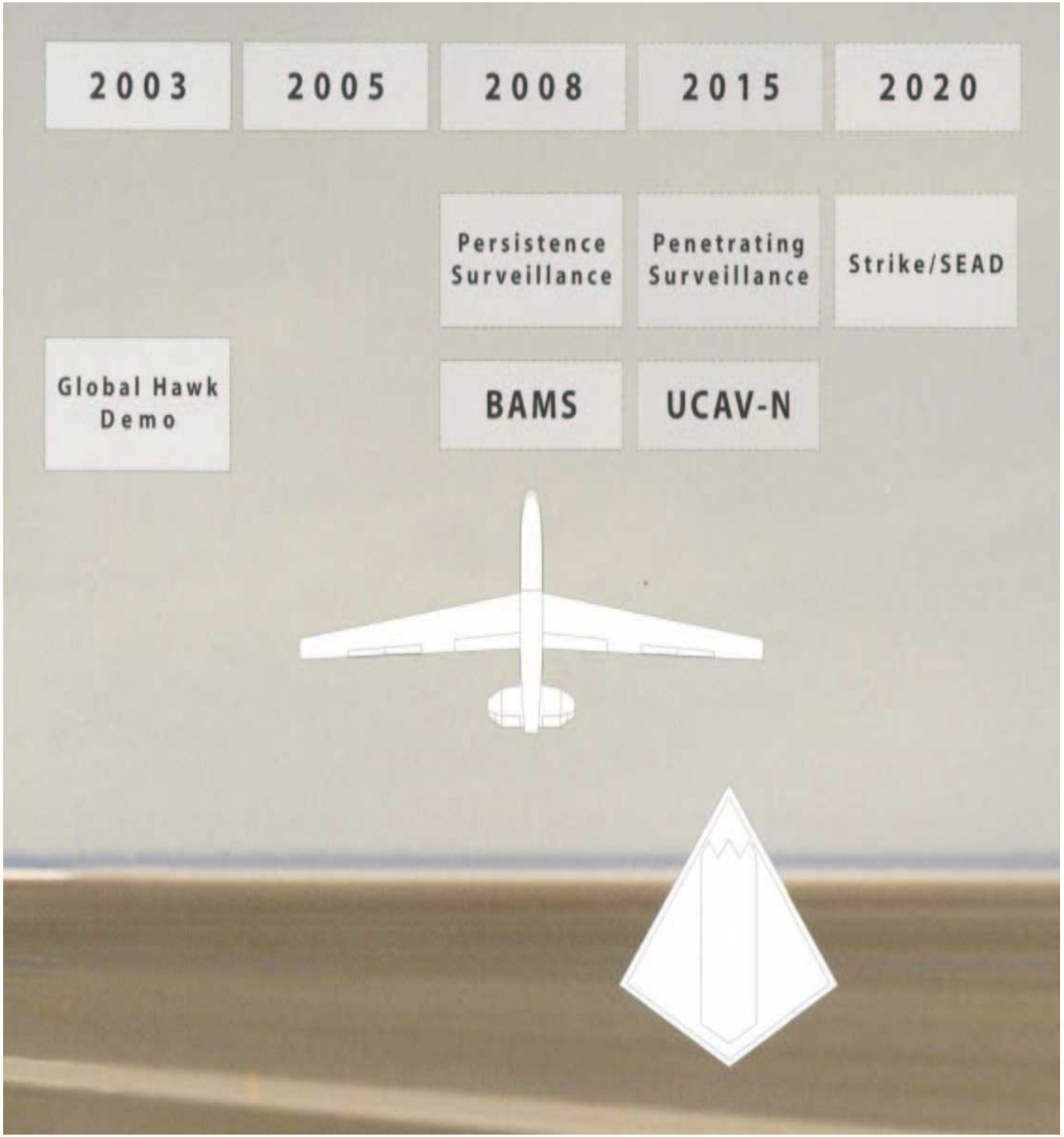
Navy Fixed-Wing Aviation Neck-Down Strategy



Marine Corps Aviation Neck-Down Strategy



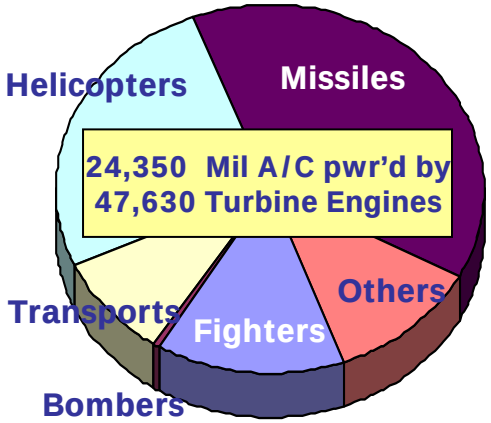
Navy Rotary-Wing Aviation Neck-Down Strategy



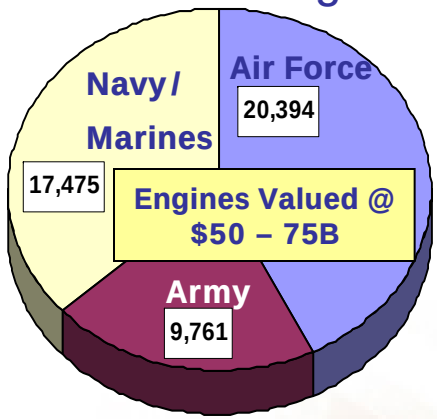
Naval Aviation UAV Strategy

Turbine Engines Power DoD

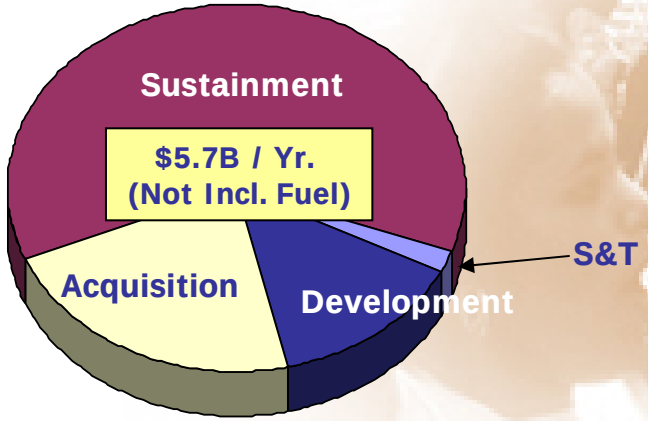
DoD's "Air" Fleet



DoD's "Turbine Engine" Fleet



DoD's "Turbine Engine" Investments



	Air Force	Army	Dept of the Navy	Total
Fighters	2,167	0	1,268	3,435
Bombers	182	0	0	182
Transports	1,817	156	201	2,174
Helicopters	200	4,698	1,389	6,287
Missiles	2,479	125	6,816	9,420
Others*	1,540	21	1,291	2,852
Total	8,385	5,000	10,965	24,350
Sustainment ($M)	2,247	200	1,100	3,547
Acquisition ($M)	631	75	568	1274
Development ($M)	559	75	165	799
Science &Tech ($M)	88	9	19	116
Total ($M)	3,525	359	1,852	5,736
Fuel – Gallons**	2.6B	0.3B	1.8B	4.7B
Fuel – Cost**	$2.6B	$0.3B	$1.8B	$4.7B

Acquisition	Aero-space	A/C	Turbine Engines
Industry Jobs	583,000	369,000	82,600
Industry Payrolls	$28.9B	$18.3B	$4.1B

*Others Include: Trainers, UAV, Recon

**FY04 Fuel Data

Navy Turbine Engine Importance

The Inventory Factor

- Over 10,000 Navy turbine engines valued at over $6B in 36 different manned aircraft types
- Over 500 ship engines, 1,000 ship generator sets, 2,000 missile/UAV engines, 5,000 GTS/APU

The Ownership Cost Factor

- The Navy burns 2B gallons of fuel/yr (1B for aircraft, 1B for ships)
- 20% SFC improvement saves $400M/yr (@ $1+/gal – but, delivered platform fuel cost is ~$500/gal)
- $1.4B/year on Navy aircraft engine maintenance costs
- Navy estimated share of JSF Life Cycle Costs for the engine is ~$30B

The System Payoff Propulsion Factor

- 40-60% of aircraft Take-Off-Gross-Weight is engine & fuel
- Propulsion system has major impact on aircraft size, weight, cost, capability

The Facts-of-Life Factor

- Aircraft get heavier with time; historically, aircraft weight increases about a pound a day
- Need to increase engine thrust every 5-7 years to retain aircraft performance

Turbine Engines are a DoD Special Interest

The Naval Operational Environment

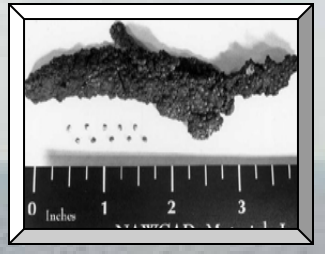
Take-Offs

Landings

Missions

Shipboard Ops

Steam Ingestion



FOD

Sand Ingestion

Salt Water Corrosion

The Naval Aviation Operating Environment
Unique Propulsion System Challenges

BASING, OPERATIONS AND ENVIRONMENT

NAVY AIRCRAFT DO EVERYTHING THAT LAND BASED AIRCRAFT DO...BUT IN A MORE HOSTILE ENVIRONMENT AND UNDER MORE ADVERSE CONDITIONS

MISSIONS
- Loiter and Cruise Segments
- Multi-Mission Capable
- V/STOL and STOVL

MARITIME ENVIRONMENT
- Highly Corrosive Salt Air / Spray
- High Humidity / Icing Conditions

CARRIER/AIR-CAPABLE SHIP OPS
- High FOD and EMI
- Limited Maintenance / Storage Space
- Limited Support Equipment (APU)
- Unique Fuel & Lube Requirements

CARRIER APPROACH
- Rapid, Precise Throttle Changes
- Bolter / Wave-Off Thrust Response
- High Hydraulic / Gearbox Loading

CATAPULT TAKEOFF AND ARRESTED LANDING
- High Impact Structural Loads
- High Thermal / Cyclic Loading
- Positive Single Engine Rate-of-Climb
- Steam Ingestion (Need for Increased Stall Margin)

AIRCRAFT CARRIER TO SCALE

TYPICAL 300'x10,000' RUNWAY

Naval Aviation Performance & Capability

Unique NAVAL Environment & Missions Drive Capability Needs

- Carrier Takeoff & Landing
- Single Engine Rate of Climb
- Small Ships & Remote Ops
- Short Takeoff & Vertical Landing
- Multi Mission Capability

Associated Performance Required

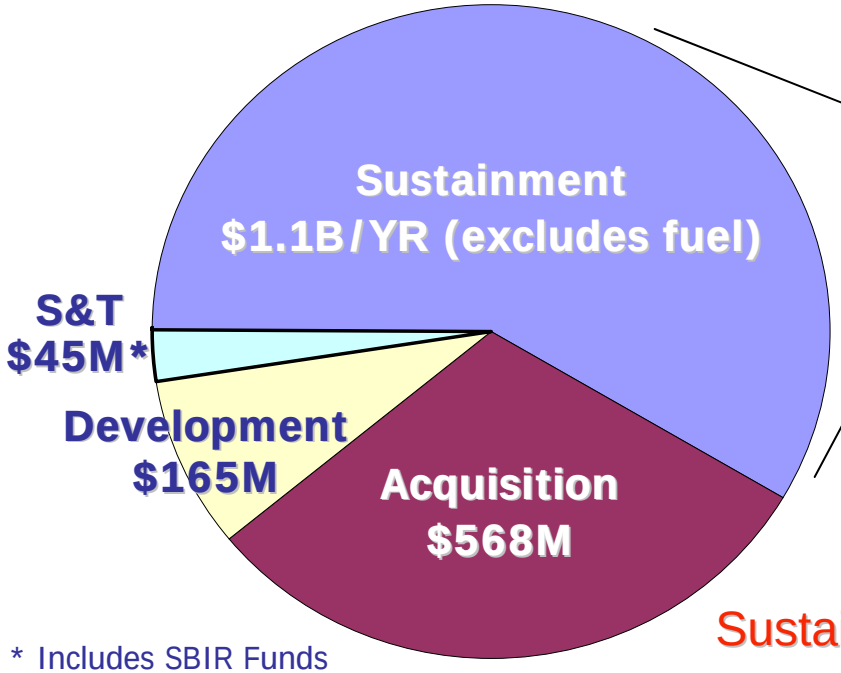
- Thrust/Weight Growth
- Reduced Fuel Consumption
- Increased Power Demand
- Survivability

Navy Airbreathing Engine Summary

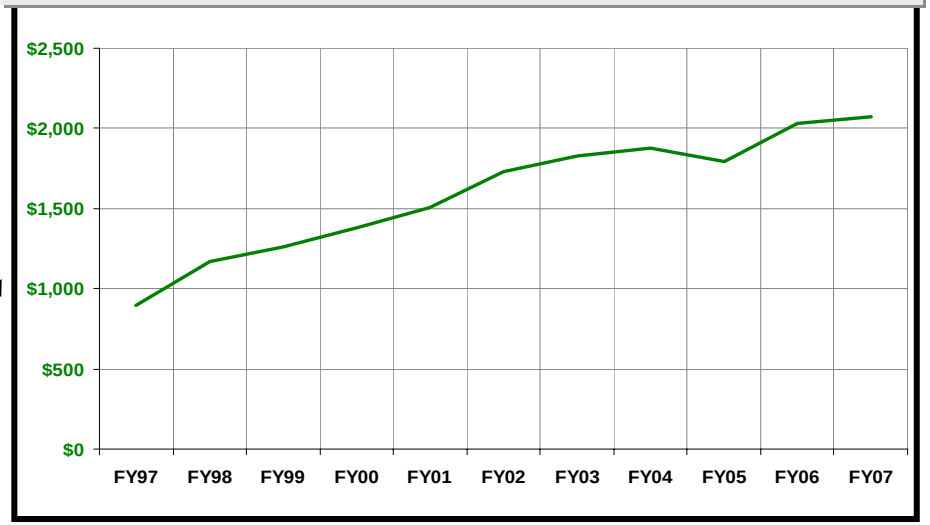
NAVY "Air" Fleet

10,965 A/C powered by 17,475 Turbine Engines

NAVY's "Turbine Engine" Investments



NAVY's "Turbine Engine" Cost/Flt Hr



13.3% Increase Per Year

Sustainment is the Primary Cost Driver

* Includes SBIR Funds

Naval Aviation Propulsion S&T Priorities

Legacy & Future Readiness

Increased reliability components, reduced maintenance costs, improved FOD robustness, reduced erosion, corrosion, repair, greater hot section durability, reduced HCF

Capability Growth

Higher thrust/power in same physical envelope, increased demand for electrical power, reduced fuel consumption, reduced weight, affordability

UAV/UCAV

Operability, low fuel consumption, power integration, low cost, inlet/nozzle vehicle integration, survivability

High Speed Weapons

Low cost, high specific thrust, high acceleration, low volume, short length

Environmental

Noise reduction, emissions reduction

Naval Aviation Unique
Propulsion & Power Technology Challenges

Technology Demonstrator Engines

Configurations & components robust to Naval Aviation environment (steam & gas ingestion, humidity, landing loads, corrosion, erosion resistance, etc)

- VTOL & F-35 STOVL configuration unique technologies – lift fan, reliable engine thrust/weight with reliable health management, high power density gearboxes, direct lift engines
- UCAV integrated total propulsion systems – Inlet/engine/nozzle, increased electrical power generation/extraction, thermal & health management, mission adaptive controls, sea-based operational utility

Materials & Component Technology Examples

Materials

- Durable thermal barrier coatings
- Erosion & environmental coatings
- High Temperature light weight blades/structures
- High Temperature disks

Navy investments focus on Naval Unique aspects

Naval Aviation Unique
Propulsion & Power Technology Challenges

- **Compression Systems**
  Lightweight, damage tolerant, robust to distorted inlet airflow, steam & hot gas ingestion tolerant
- **Combustion Systems**
  Contaminated fuel tolerant, reduced weight, reduced emissions, many thermal cycles, operability
- **Turbine Systems**
  Lower ownership costs, repairability, sea salt & steam-ingestion, high fuel/air ratio resistant, many thermal cycles, corrosion resistant, sand tolerant, repairable, fault detectable
- **Mechanical Systems**
  High impact, corrosion resistant bearing & seals, elimination of lubrication system
- **Controls/Prognostics**
  Detect/characterize foreign objects, sea spray, ice, steam, erosion particles; adaptive to counter engine wear, battle damage, life extension; life management for reduced logistics; complex architecture management, throttle response adaptable, EMI resistant

Navy investments focus on Naval Unique aspects

Naval Aviation Unique
Propulsion & Power Technology Challenges

- **Exhaust Nozzle**
  Reduced noise/weight/cost, thrust vectoring, survivable, repairable
- **Fuel Systems**
  Single fuel for all Naval applications, Naval environment compatible
- **Lubricants**
  Single lubricant for all Naval applications, Naval environment compatible
- **Drive Systems**
  Contaminant tolerant, long duration operation with loss of lubricant, Corrosion resistant, reduced weight
- **Electrical Power Systems**
  Compact high density power, thermal management, flexible power control, fault tolerant, humidity tolerant concepts, shock & vibration, fuel cells
- **Alternate Propulsion System Concepts**
  Variable cycle, Combined Cycle, Hybrid Cycle, PDE

Navy investments focus on Naval Unique aspects

Agile Combat Support / Enterprise & Platform Enablers

Turbine Engine Capability Enhancements
– Emerging and Future –

Payoffs:

- Performance/durability improvements
- F135/F136 growth
- 2X hot section life
  (required for Next Generation Long Range Strike)
- Reduction of High Cycle Fatigue failures
- Integrated thermal management system
- High power extraction

Turbine Engine Life Management Technologies

Payoffs:

- Increased high hot time
- Higher reliability compression systems
- Increased operability
- -75% Class-A failures
- -10% sustainment cost
- 2X greater time-on-wing

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Agile Combat Support / Enterprise & Platform Enablers

Turbine Engine Capability Enhancements
– Fielded Systems (AE3007H, F119, F100, F110, F414) –

Technologies & Payoffs:

- Integral starter generator – in-flight engine restart capability
- Advanced materials – improved durability & weight reduction
- Parts life tracking systems – extended time-on-wing
- Engine fault diagnostics – reduced maintenance actions
- Airfoil damage tolerant design system – reduces unscheduled engine removals, extends time-on-wing
- Turbine disk heat transfer validation – enables life extension
- Advanced fan, compressor & turbine – +20% thrust, -4% SFC or 6000 hr life

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VAATE Addresses Naval Aviation Needs

Naval Aviation Propulsion S&T Priorities	VAATE Investments
Legacy and Future Readiness	Agile Combat Support/Enterprise & Platform Enablers
Capability Growth	Air Superiority/Protection
UAV/UCAV	Persistent C2ISR
High Speed Weapons	Strike/Persistent Engagement
Environmental	Multi-Mission Mobility