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Gas Turbine Engine R&D for Shipboard Applications

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Outline

- *NSWCCD Organization*
- *Navy Current Fleet Gas Turbine Engines*
- *NSWCCD Philadelphia Engine Test Facilities*
- *Gas Turbine R&D Programs*
- *Future Fleet Direction*
- *Gas Turbine R&D Objectives & Goals*
- *Navy Gas Turbine R&D Strategy - Teaming*
- *Potential Gas Turbine R&D Programs*



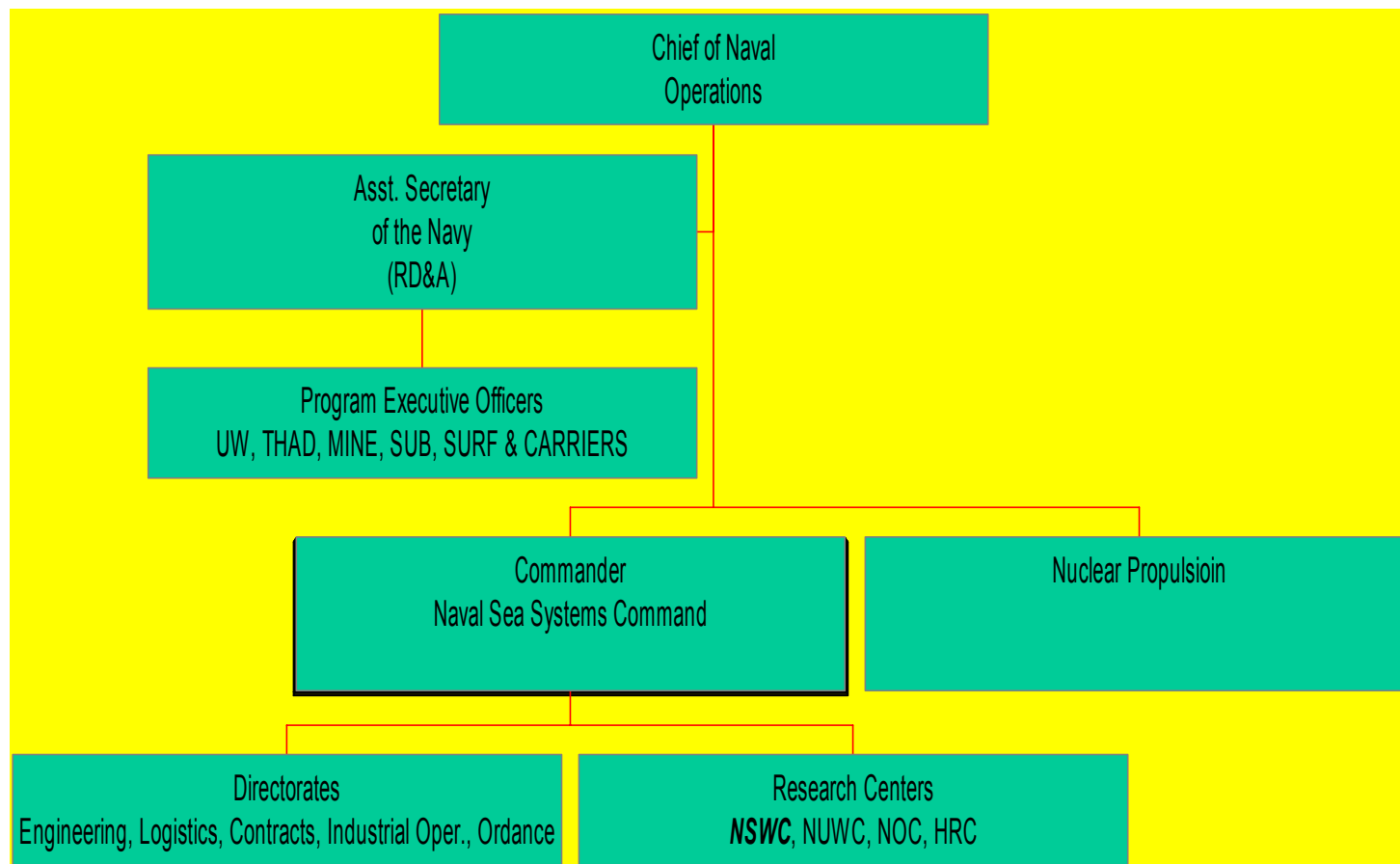
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NAVSEA Organization





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NSWCCD Organization

- **NSWCCD is Power Systems Lead for Surface Ships**
- **Gas Turbine R&D group from Annapolis transitioned to NSWCCD Philadelphia 10/99**
- **Life Cycle Management (LCM) of Power Systems transitioned to NSWCCD Philadelphia 10/99**
- **In Service Engineering Agents (ISEA) remain in Philadelphia**
- **NSWC Philadelphia: ~ 2000 employees**



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Navy Current Fleet Gas Turbine Engines

- **GE LM 2500: 29,400 Bhp (~22MW)**
 - Cruisers (CG 47 Class) - 4 propulsion engines
 - Destroyers (DD 963, DDG 51 Classes) - 4 propulsion engines
 - Frigates (FFG 7 Class) - 2 propulsion engines
- **Allison 501-K17 or K34 (~3MW)**
 - Cruisers (CG 47 Class) - 3 gas turbine generators
 - Destroyers (DD 963, DDG 51 Classes) - 3 gas turbine generators
- **Allied Signal TF40B: 3955 Bhp (~2.9MW)**
 - LCAC - 4 propulsion engines
- **Sundstrand Titan T62T-40-7: 50 Bhp**
 - LCAC - gas turbine generator



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NSWCCD Philadelphia Engine Test Facilities

- **Land Based Evaluation Site (LBES):**
 - DDG 51 Power Plant & Controls (LM 2500)
 - DDG 51 & CG47 Ship Service Gas Generator (501K)
- **Inter-Cooled Recuperative (ICR) Engine Test Facility**
- **Integrated Power System (IPS) Test Site**
- **Large Diesel Engine Test Cells (2) (up to 4000 HP)**
- **Small Diesel Engine Test Cell (up to 750 HP)**



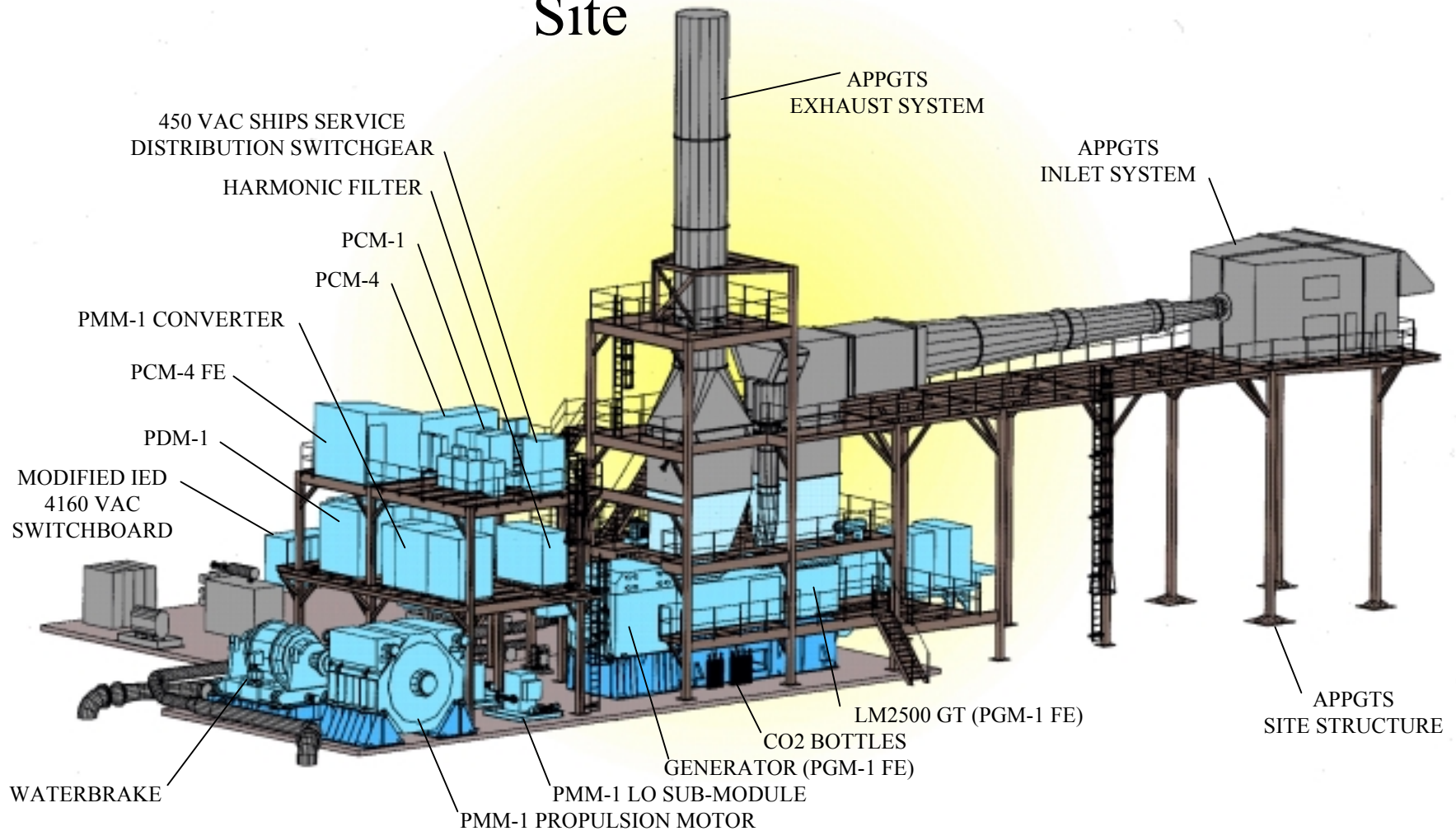
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Integrated Power System Land Based Engineering Site





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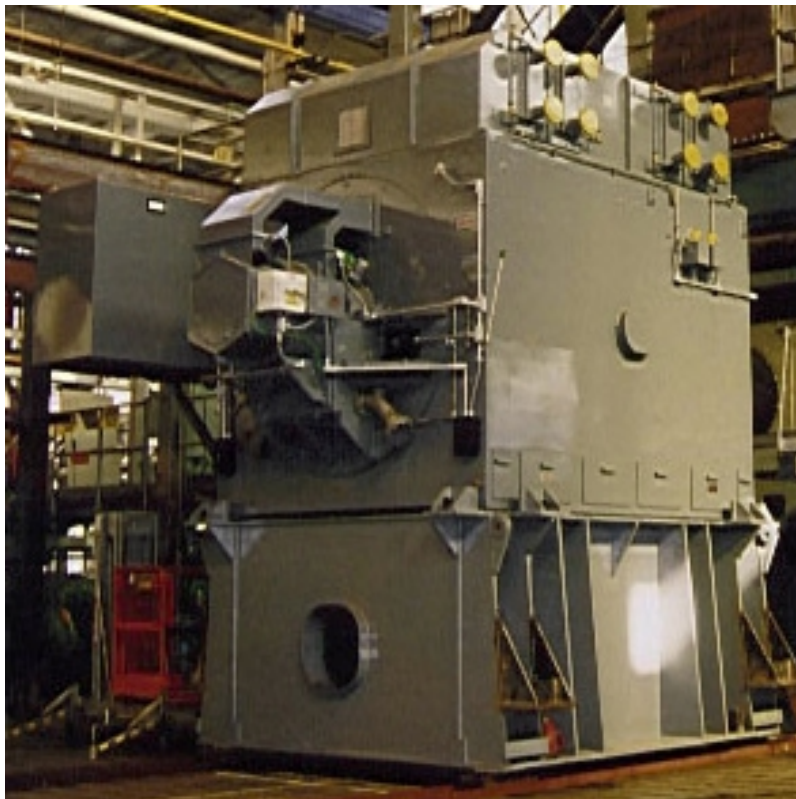
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INTEGRATED POWER SYSTEM

PROPULSION GENERATOR



- 21 MW - 26.25 MVA
- 4160 V - 3 Phase
- 60 HZ - .8 Pwr Fctr
- 2 Pole - 3600 RPM
- 97 % Efficiency
- 50,050 KG & 3.4m(H)
- 4.7m(L) - 4m(W)
- Brush Electric
Company (UK)



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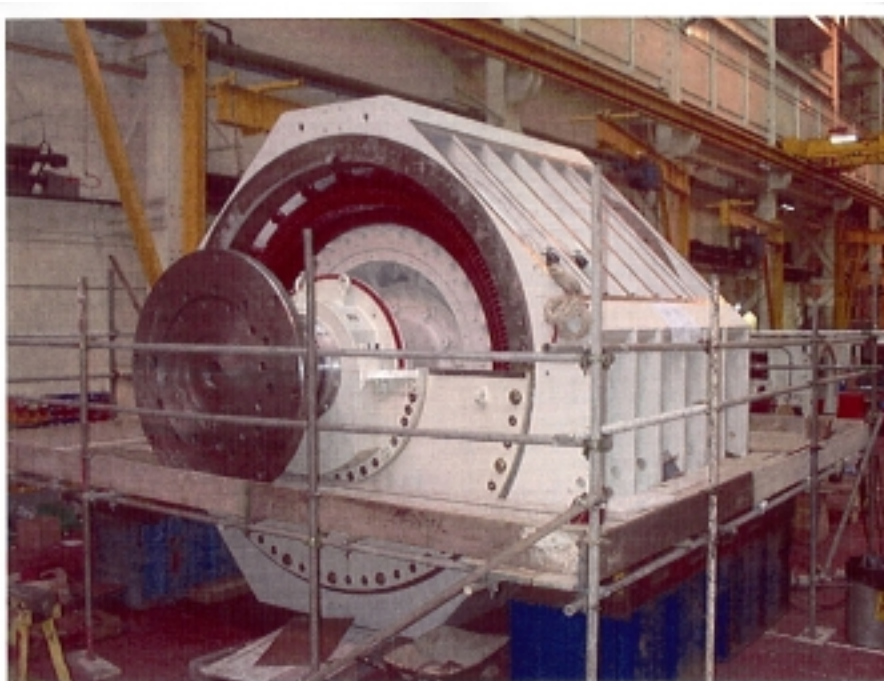
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INTEGRATED POWER SYSTEM

PROPULSION MOTOR



- **19 MW - 25,500 SHP**
- **0-3700 V - 0-15 HZ**
- **12 Pole - 150 RPM**
- **15 Phase**
- **96 % Efficiency**
- **117,400 KG & 4m(H) - 4.35m(L) - 4.5m(W)**
- **Alstom Electrical Machines (UK) / ex-GEC**



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NSWCCD Philadelphia Engine Test Facilities Cont'd

- **Large Engine Test Site (Proposed Milcon 2003):**
 - Will provide capability to test larger engines anticipated for electric drive ships
 - 1 cell capable of generating up to 100MW
 - Plan to send power to the grid
 - 1 cell with a 75,000 HP waterbrake
 - Plan to promote facility as a National Gas Turbine R&D Center (asset for electric utility & other customers)



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NAVAL SURFACE WARFARE CENTER **NSWC**

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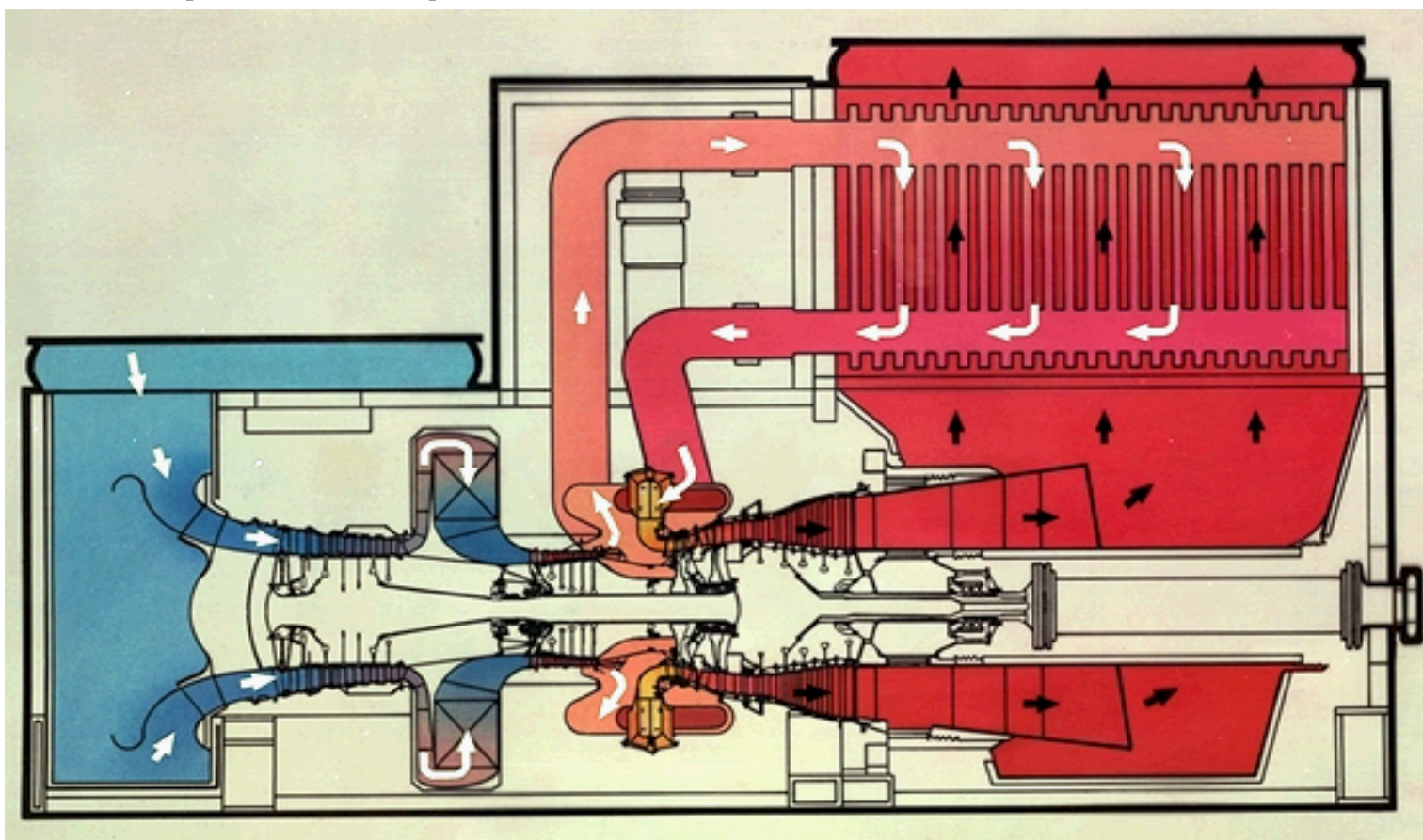
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NAVSEA Gas Turbine R&D Program:

ICR (WR-21)





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Gas Turbine R&D Programs

- ***ICR Engine Technical Challenges:***
 - Recuperator
 - Thermal Cycling & Compact Design
 - Combustor
 - High Comb. Inlet Temperature & Large Range of Air Fuel Ratios
 - Combustor Manifold
 - High Temperatures & Gradients
- ***ICR Engine Progress To Date:***
 - 1,674 Hrs of System Testing
 - Demo 25% Fuel Savings & 29,000 HP on 100°F day
 - Demo of All Maneuvers
 - Recuperator Design Model Validated



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Gas Turbine R&D Programs

ICR Engine Remaining Development:

- US Navy Contract
 - 500 Hr Endurance Test at NSWC Phila
 - Smoke & Emissions/C & V
- Royal Navy Gas Turbine Alternator Program
 - Strain Gage HPC Casing Treatment
 - Controls Optimization
- Qualification Testing:
 - Performed by Royal Navy
 - Shock Test
 - Performed by French Navy
 - 3,150 Hr Endurance Test
 - Noise Tests (Airborne & Structureborne)



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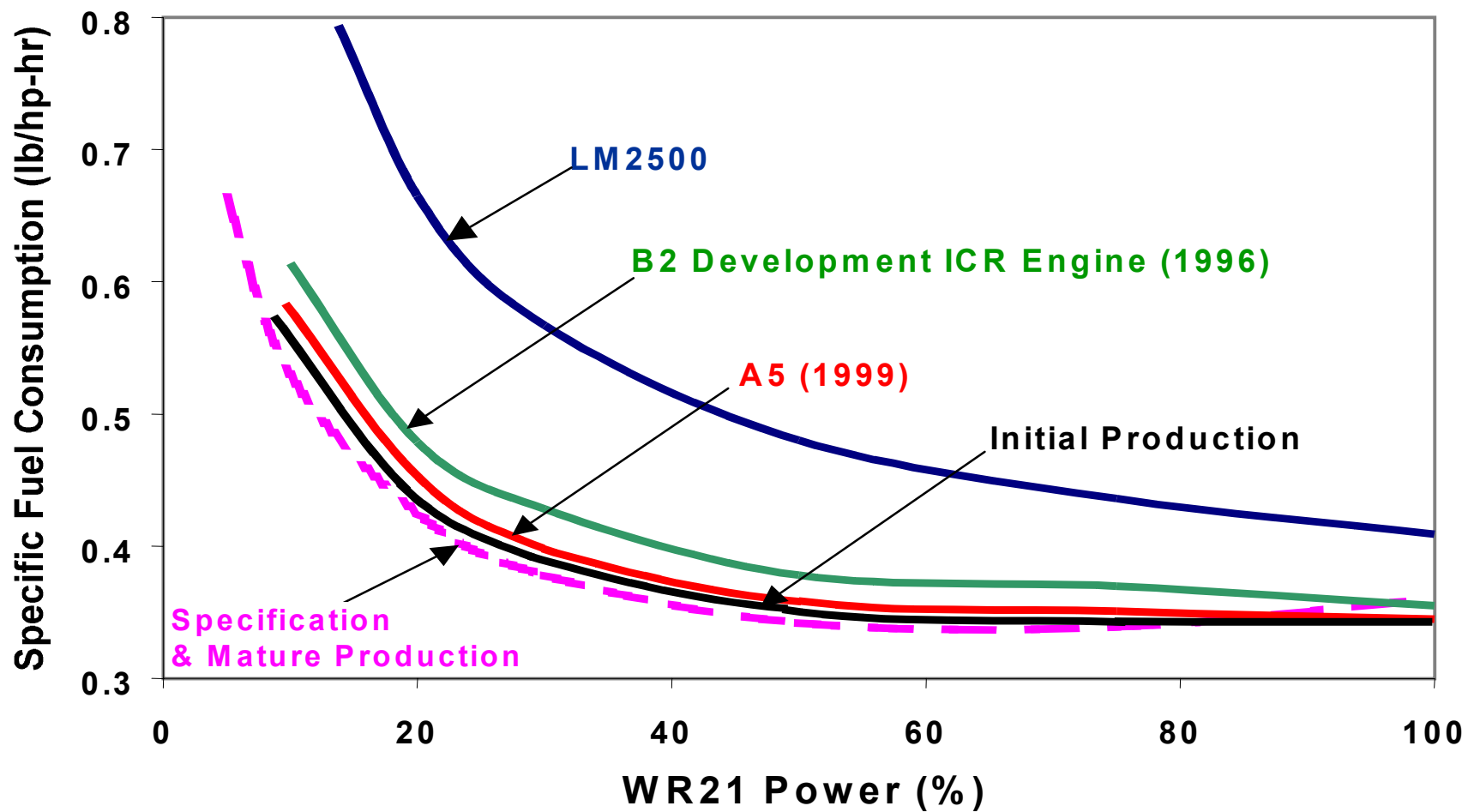
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Performance





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Gas Turbine R&D Programs

Shipboard Generator Set Study

- **Two contracts awarded:**
 - Rolls Royce Allison
 - Solar Turbines
- **Concept Feasibility Applications Considered:**
 - Ship Service Gen Set on a Ship configured with Mech Drive Propulsion supplying Underway, At-Anchor & Emergency Power: 2.5MW w/bleed (3MW w/o bleed), 450 VAC, 3 phase, 60 Hz
 - Power Generation Module on a Ship configured with Electric Drive Propulsion supplying At-Anchor, Emergency (&perhaps Propulsion) Power: 3-10 MW, 4160 VAC, 3 phase, 60 Hz
- **Concept Feasibility Studies Completed in 1Q FY00**
 - Navy to review study results



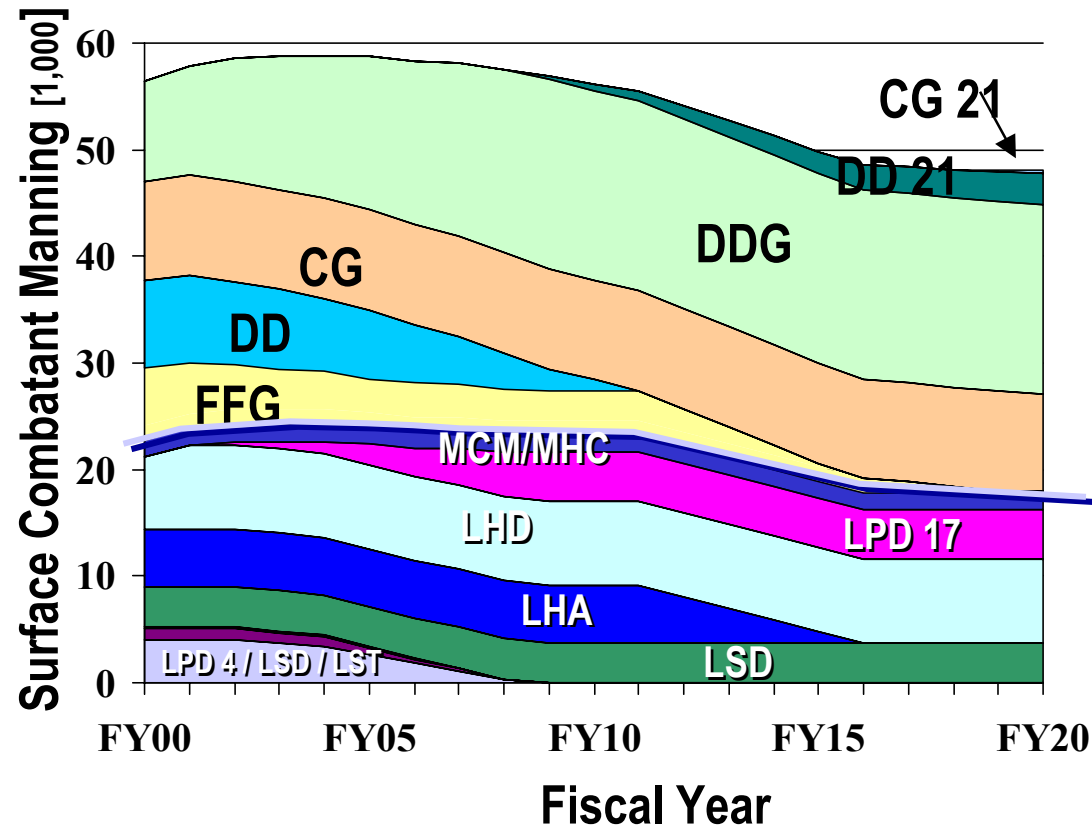
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Future Fleet Direction



- **New ships and legacy fleet must be totally**

- Interoperable
- Compatible
- Supportable

- **Legacy Fleet**

- Is sizable
- Will be with us for some time
- Must be supported



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Navy Gas Turbine R&D Objectives

Investigate, develop, and demonstrate integrated concepts and technologies for existing and future Navy gas turbine power plants to reduce *total ownership costs*, increase *combat effectiveness* and *reduce vulnerability* through:

- Improved fuel efficiency
- Increased reliability
- Reduced maintenance
- Reduced environmental impacts
- Reduced infrared, radar, and noise signatures



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Fleet Gas Turbine Operational Goals

Goals	Reduced Workload	Improved Reliability (MTBF hrs)	Reduced Fuel Consumption lb/HP-hr	Increased Power Density & Specific Power	Reduced IR Signature	Reduced Environmental Impacts
Current Baseline: LM2500	0% personnel 0 days	LM2500: 1000 hrs	0.52	0.55 HP/Lb, 180 HP-s/lb	1000°F	Nb _x 0%, CO ₂ 0%
Near Term: (2005)	50% personnel 90 days	2200 hrs	0.44	10%	< 1000°F	Nb _x 15%, CO ₂ 15%
Mid Term: (2006 - 2020)	75% personnel 180 days	4400 hrs	0.39	50%	< 1000°F	Nb _x 50%, CO ₂ 25%
Far Term: (2020 - out)	98% personnel 365 days	5000+ hrs	0.34	100%	< 1000°F	Nb _x 75%, CO ₂ 50%



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New Ship Acquisition Strategy

- Acquisition reform is demanding off-the-shelf commercial products
- New ships & power systems will be designed by contractor teams:
 - DD21 Blue Team > BIW & Lockheed Martin
 - DD21 Gold Team > Ingals & Raytheon
- Navy will select best ship based on cost/performance
- Industry decides how best to meet objectives
- Gas Turbine R&D programs necessary to ensure commercial OTS engines meet Navy requirements



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R&D Program Strategy

- Provide **technology** for insertion into new & existing fleet turbines
- Focus on Navy unique requirements
- Leverage opportunities to achieve common goals (IHPTET):
 - Advanced Turbine Systems/Vision 21 (DOE)
 - OEM's
 - IHPTET & Beyond (DOD)
 - SBIR's
 - Universities
- Prioritize efforts IAW:
 - Critical fleet requirements
 - New ship deployment schedules
 - Available funding



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Potential Gas Turbine R&D Programs

- Develop Conditioned Based Maintenance (CBM) tools to reduce maintenance requirements
- Develop engine enhancements to increase engine efficiency at part and full load via:
 - Trapped Vortex Combustors to allow gas turbine reheat and increased specific power
 - GE LM 2500 using WFI/VATNs
 - Rolls Royce Allison 501-K using WFI
 - WR-21 ICR GT engine with WFI/SPRINT
 - Investigation of Variable Stator Blades (VSB) to increase part-load performance
 - Investigation of gas turbine / fuel cell hybrid system



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Summary

- Navy Machinery R&D, LCM, & ISEA now co-located at NSWCCD Philadelphia
- NSWCCD Philadelphia has Gas Turbine, IPS, & Diesel Test facilities available
- Future ships engines will be COTS variants selected by shipbuilder
- Future Navy sponsored Gas Turbine R&D programs will be **collaborative** with other agencies to achieve common goals at reduced cost
 - Gas Turbine component development will most likely be favored
 - CBM tools will be developed to drive down maintenance costs