

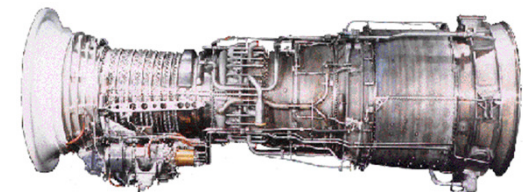
Advanced Propulsion Technologies For Electric Ship Architectures



Sanjeev Kakkar
Director Business Development
Military Systems Operation
GE Aviation
sanjeev.kakkar@ge.com



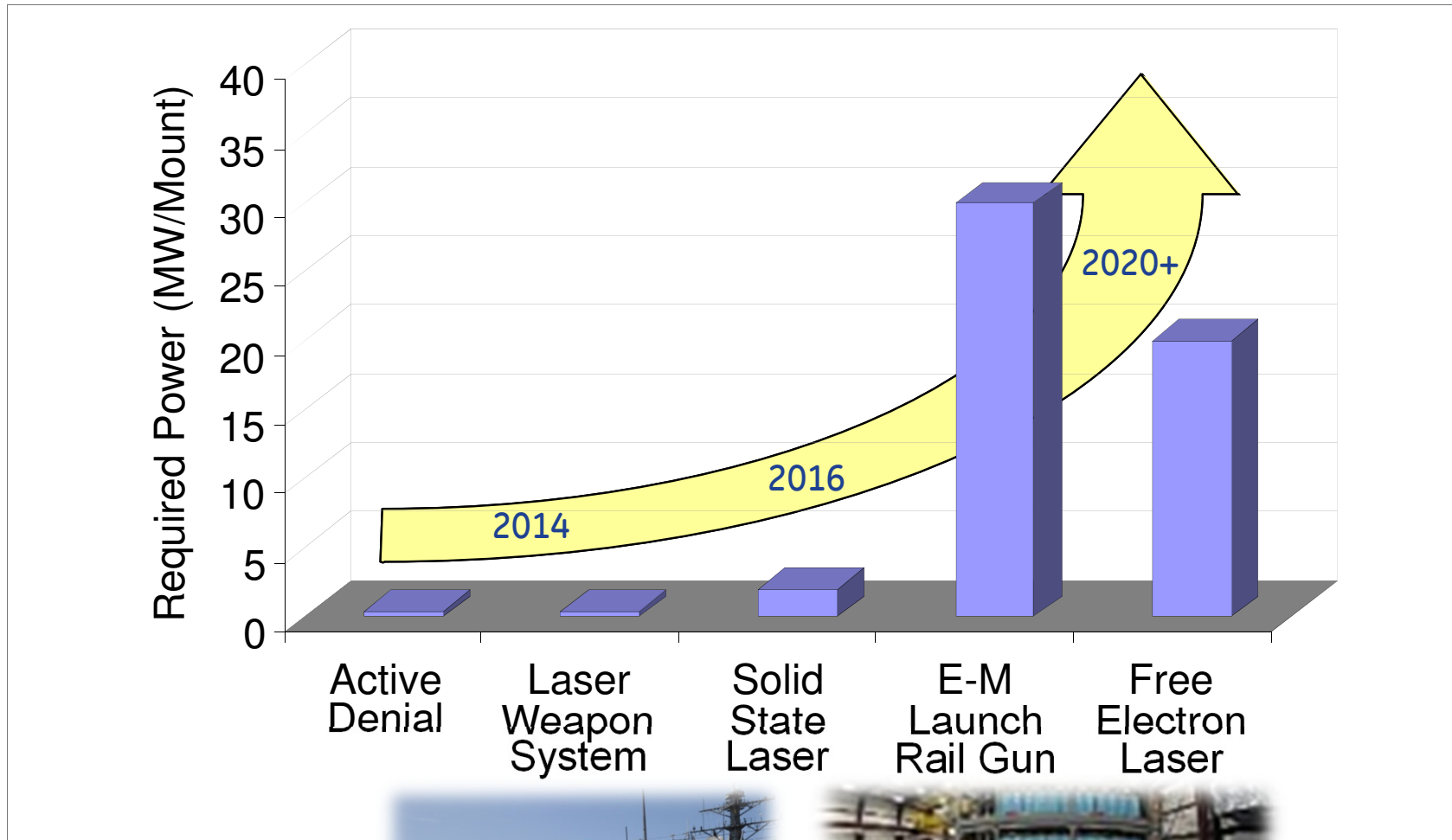
imagination at work



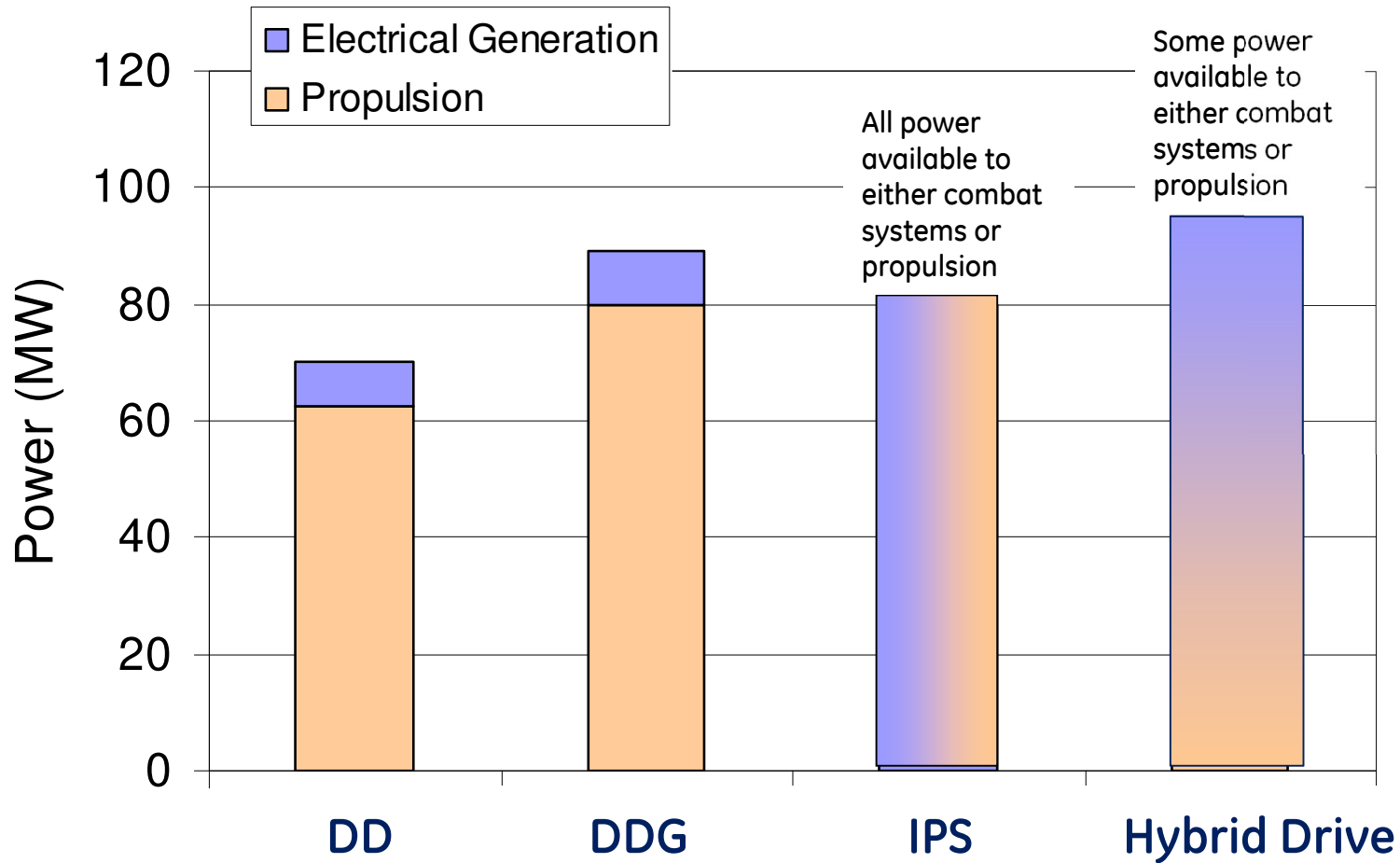
GE Proprietary Information

Warship Power Demands

Energy Consuming Combat Systems



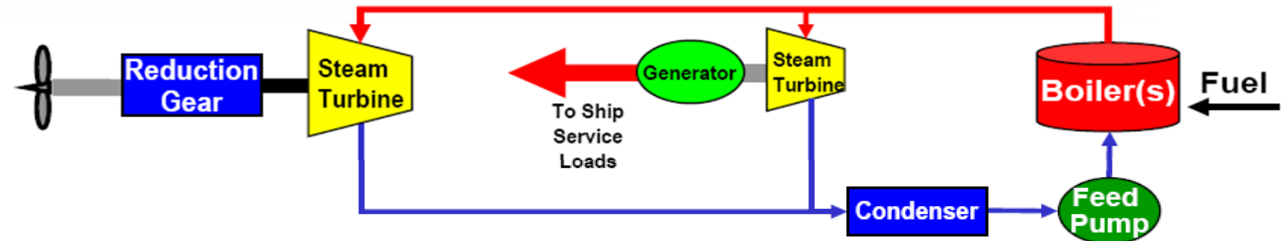
Electrical Power Apportionment Propulsion vs. Combat System



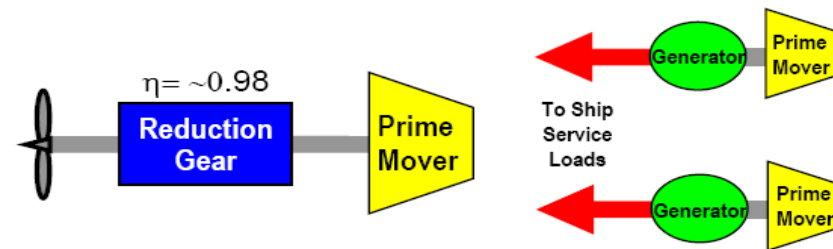
Integration Trends – More Electric

“Integrated” System: Combustion machinery (boiler, engine) provides propulsion & ship service power simultaneously

Older ships integrated on steam side

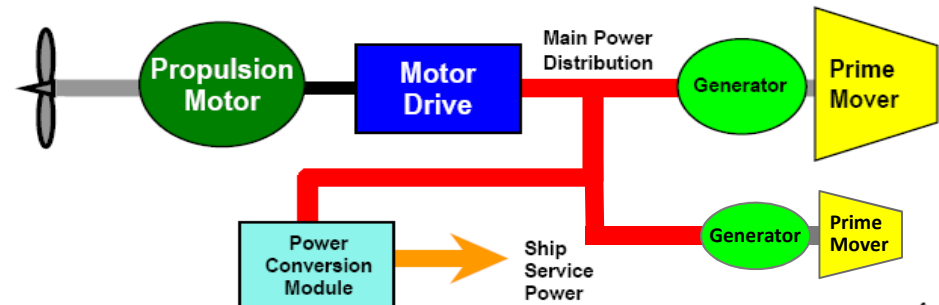


“Integration” lost in transition to internal combustion engines (gas turbines & diesels)



Integrated Power System (IPS) brings back “integration” on the electrical side, enabled by

- Solid state power electronics
- Multi-Megawatt Motor Drives
- Automated Controls

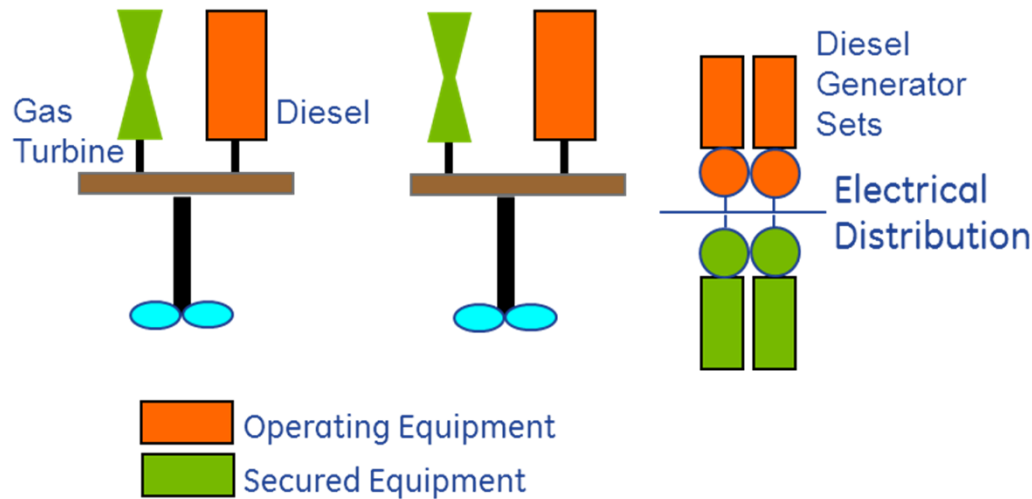


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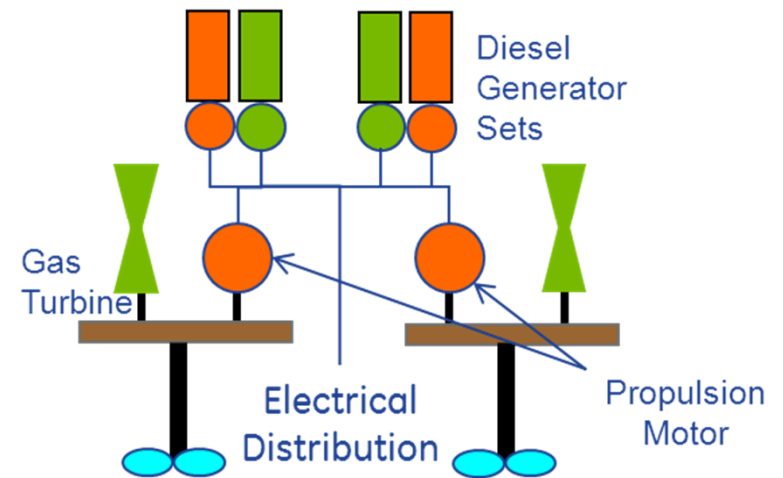
Hybrid Drive Approach



2 Gas Turbine Mechanical Drive



2 Gas Turbine Hybrid Electric Drive



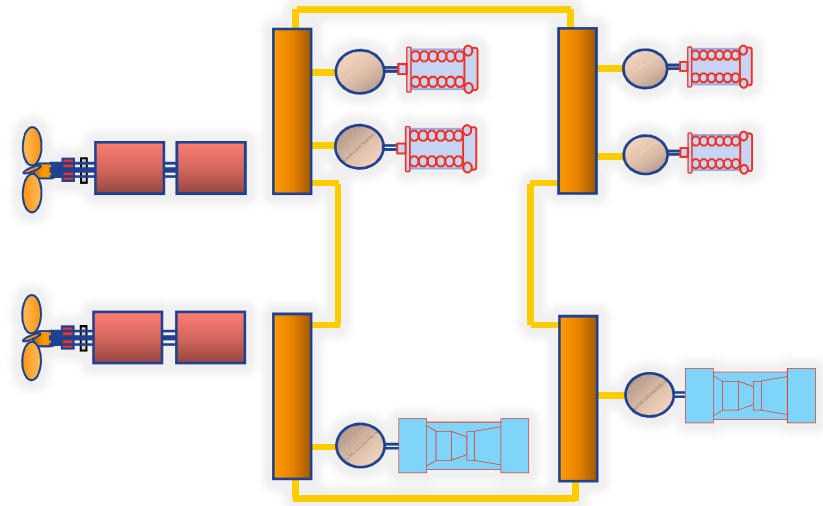
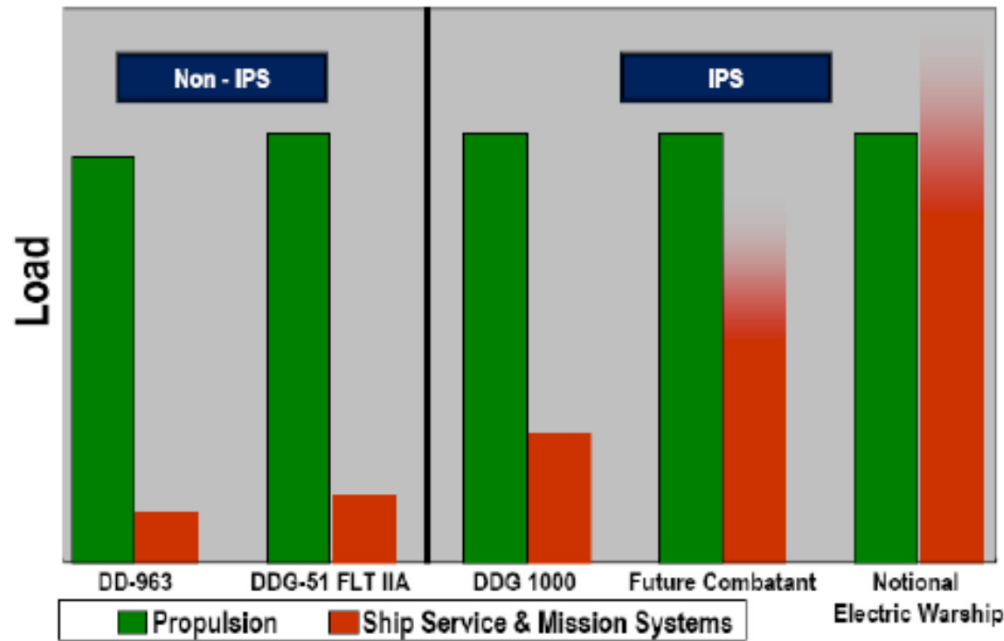
Hybrid Electric Drive (HED) Concentrates the load

- Reduces need to operate propulsion gas turbines at low power
- More heavily loaded prime movers operate more efficiently

Motor(s) and drive(s) can replace propulsion engine(s), reducing total number of engines installed

Integrated Propulsion Systems (IPS)

Naval applications










Advantages

1. Flexible power distribution
2. Increasing electrical demands for weapons
3. Can place engines anywhere in ship
4. Can run engines more efficiently
5. Reduced number of prime movers
6. Improved commonality/modularity
7. Zonal survivability
8. Fuel cell integration

Building on a Marine Power Legacy

GE powers 500 ships
in 33 world Navies

GE welcomes our most recent Navy programs...

- | | |
|--|--|
|  Turkey <ul style="list-style-type: none">• MILGEM Corvette |  India <ul style="list-style-type: none">• P17 Frigate• P71 Aircraft carrier |
|  Australia <ul style="list-style-type: none">• LHD Amphibious Assault Ship• Air Warfare Destroyer (AWD) |  South Korea <ul style="list-style-type: none">• KDX III Destroyer• PKX Fast Patrol Boat• FFX Frigate |
|  France and Italy <ul style="list-style-type: none">• FREMM Frigates |  Spain <ul style="list-style-type: none">• LHD Amphibious Assault Ship• F100 Frigate |
|  Germany <ul style="list-style-type: none">• F125 Frigate |  United States <ul style="list-style-type: none">• Littoral Combat Ship• LHD 8, LHA 6, LHA 7 Amphibious Assault Ship• DDG51 Destroyers |
|  Japan <ul style="list-style-type: none">• 25DDX Destroyer• 26DD Destroyer | |

Joining the Navy programs of...

Algeria, Bahrain, Brazil, Canada, Denmark, Egypt, Greece, Indonesia, Israel, Lithuania, Morocco, New Zealand, Norway, Pakistan, Peru, Poland, Portugal, Saudi Arabia, South Africa, Taiwan, Thailand and Venezuela



Experience across naval vessels

GE has been supplying electrical power & propulsion systems for modern Naval ships for over 40 years

40 IPS solutions

Integrated Full Electric Propulsion for major warships, including shock-proof, noise-quiet and high resilience

35 Hybrid solutions

Gas Turbine & Diesel Hybrids including shock-proof, noise-quiet and PTI/PTO capabilities

18 Specialist vessels

Ice Class & noise-quiet propulsion

Family of engines



Number produced or ordered

LM6000PC/PG

- 57,000/70,300 shaft horsepower
- 42% thermal efficiency



1,216

LM2500+G4

- 47,370 shaft horsepower
- 39% thermal efficiency



391

LM2500+

- 40,500 shaft horsepower
- 39% thermal efficiency



677

LM2500

- 33,600 shaft horsepower
- 37% thermal efficiency



2,400

LM500

- 6,130 shaft horsepower
- 32% thermal efficiency



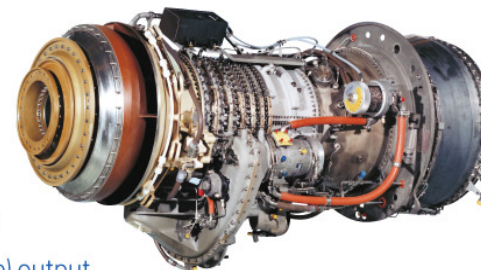
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Combined with a GE exhaust heat recovery system will result in fuel efficiencies > 50%



LM500

The only gas turbine on navy patrol ships and other small vessels



- 4,636 kW (6,130 shp) output
- 269 gm/kWh SFC (32% efficiency)
- 154 marine and 15 industrial engines delivered or on order including 68 units for the Korean PKX B patrol boats
- 2 million operating hours
- 23 million flight hours on parent



Korean PKX



Danish Stanflex



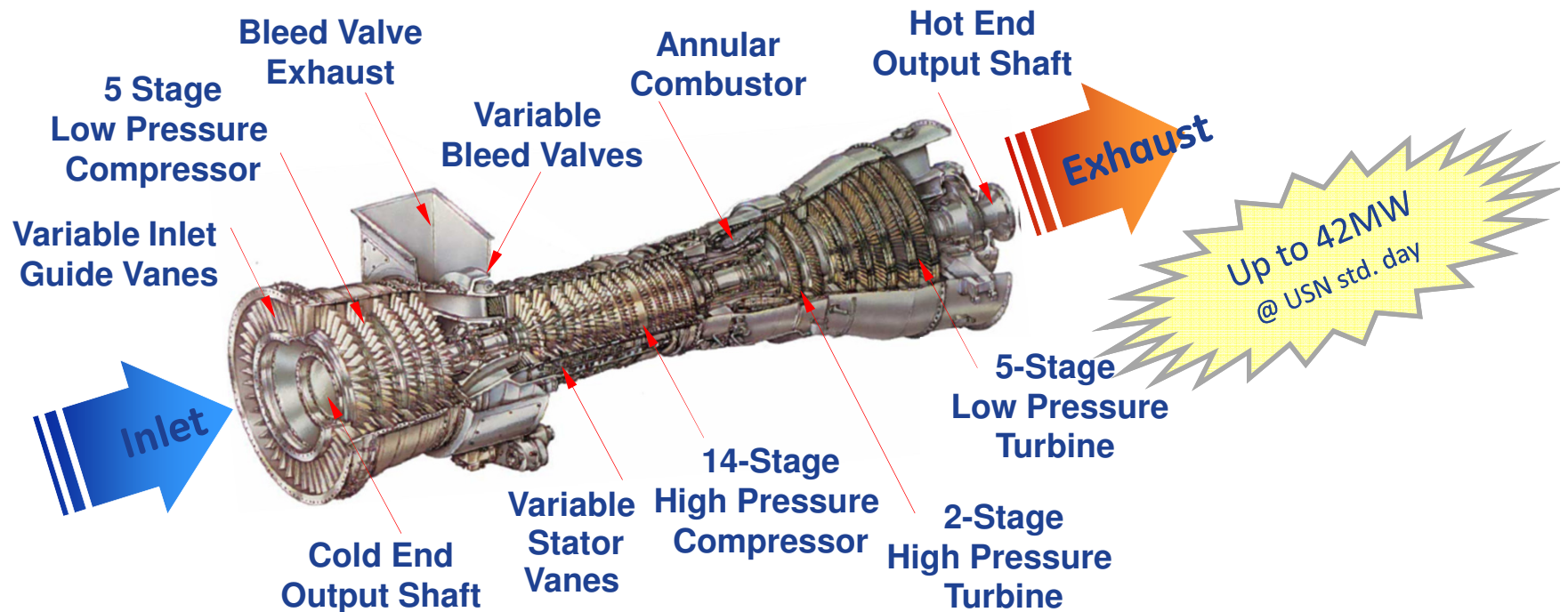
Japanese Hyabusa-class Kumotaka

May be the right choice for India's Next-Gen guided missile ships



imagination at work

LM6000 Marine Gas Turbine



Two-shaft axial flow gas turbine with 42% thermal efficiency

- Power taken directly from LP shaft without separate PT
- Highest simple cycle power & efficiency in the industry

More than 1100 engines fielded; 70-90 units produced each year

- 25M op hours in industrial applications
- 700K op hours in commercial marine applications such as FPSO ships

LM6000 Marine Package Certification

Dec 2015 Massa Italy

GE completed marine package testing for Lloyds Naval and RINA

Demonstrated engine power up to 42MW



Exhaust Heat Recovery Systems

Engine exhaust is free and available energy

- Increases output with no added fuel consumption
- Up to 10% improvement for diesels; up to 30% for gas turbines
- Increases output with reduced overall emissions

Flexible shipboard applications

- Additional service power generator
- Part of IPS/electric drive architecture
- Added shaft power using mechanical drive



Complement to gas turbines

- Takes advantage of high exhaust temperature & flow rate
- Fuel consumption of combined system results in ~ 50% efficiency



GE Proprietary Information

Waste heat to power CO₂-based power cycle

Echogen heat engines



1.5MW marine
prototype ready
2017

Scalable system platform from 200kW to 45MW+

Ideal for heat source temperatures from 200°C to > 540°C range

Efficiencies of over 30% in a small system footprint

Favorable project economics - smaller components, reduced footprint & costs

Competitive vs. steam or Organic Rankine Cycle alternatives

Conclusions



Architectures will continue “*more electric*” evolution -- All electric or hybrid:

- Large ships: All electric
 - Larger Gas Turbines
 - More volume for electric drive components
 - More electric weapons greater need for power flexibility
- Small ships: Hybrid
 - Smaller Gas Turbines
 - More volume for electric drive components

GE can provide an integrated solution



The lone Sailor keeps the watch...



imagination at work



GE Proprietary Information