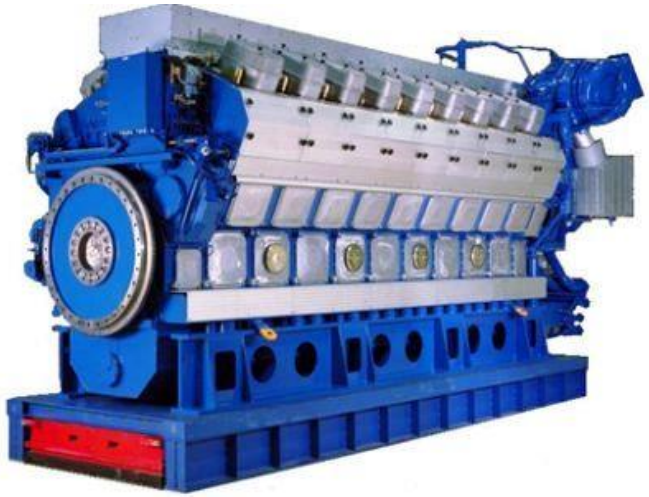
Massachusetts Institute of Technology

Center for Ocean Engineering
Naval Construction & Engineering Program
Department of Mechanical Engineering

DDG(X): Fuel-Efficient Destroyer

Presented by: LCDR Douglas Jonart
LT Aaron Dobson
LT Adam Jones

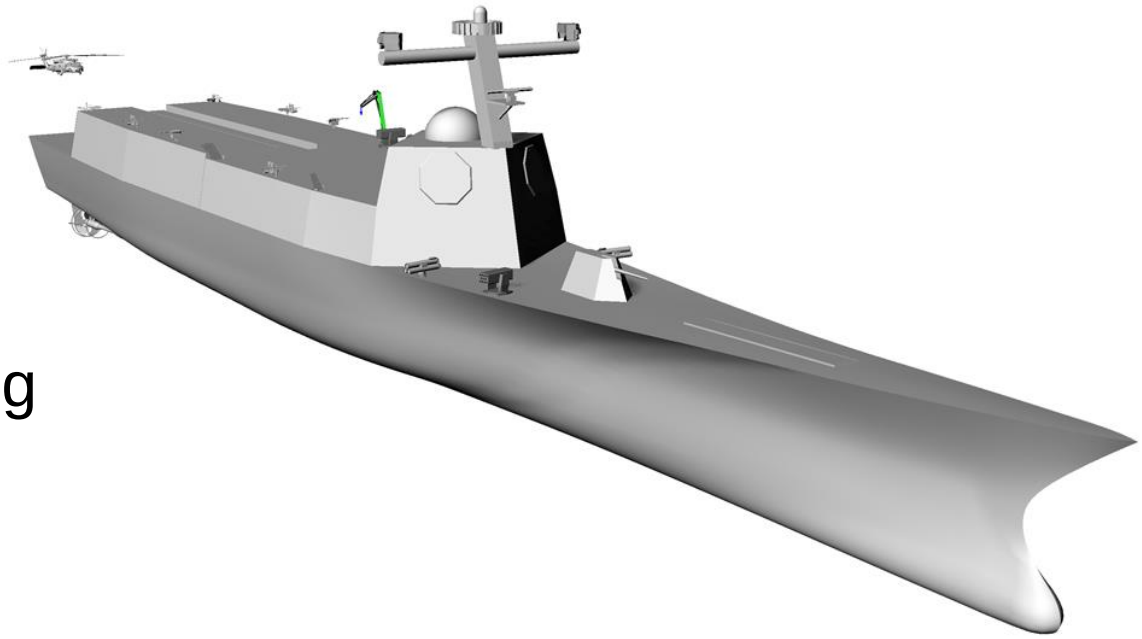
30 April 2014



Key Takeaways

Center for Ocean Engineering
Naval Construction & Engineering Program
Department of Mechanical Engineering

- **By optimizing a hullform for efficiency, fuel consumption was reduced 14%**
- **Using improved engine selection technique and optimizing loading reduced fuel consumption by more than 30%**

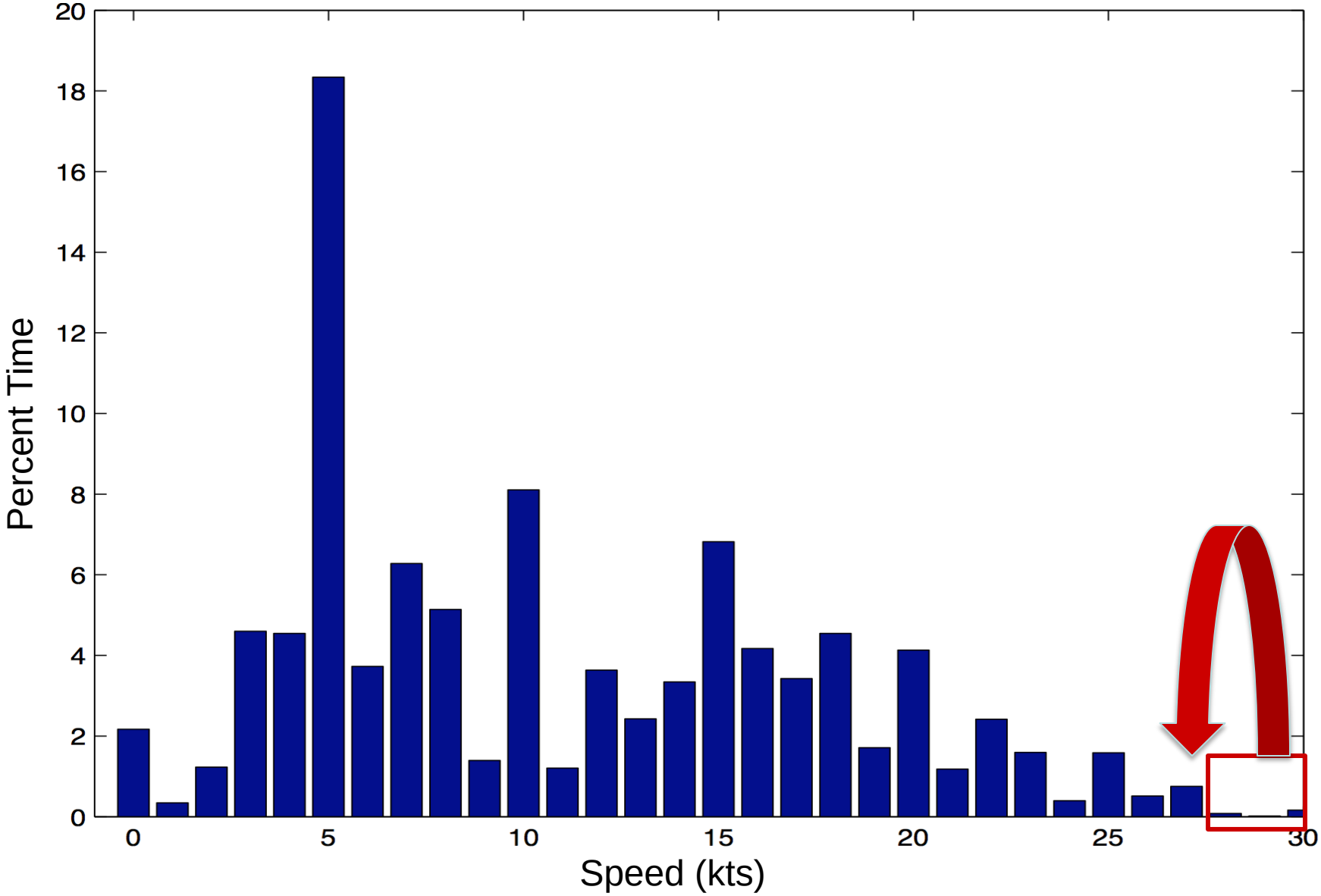


- Without sacrificing capability

Massachusetts Institute of Technology

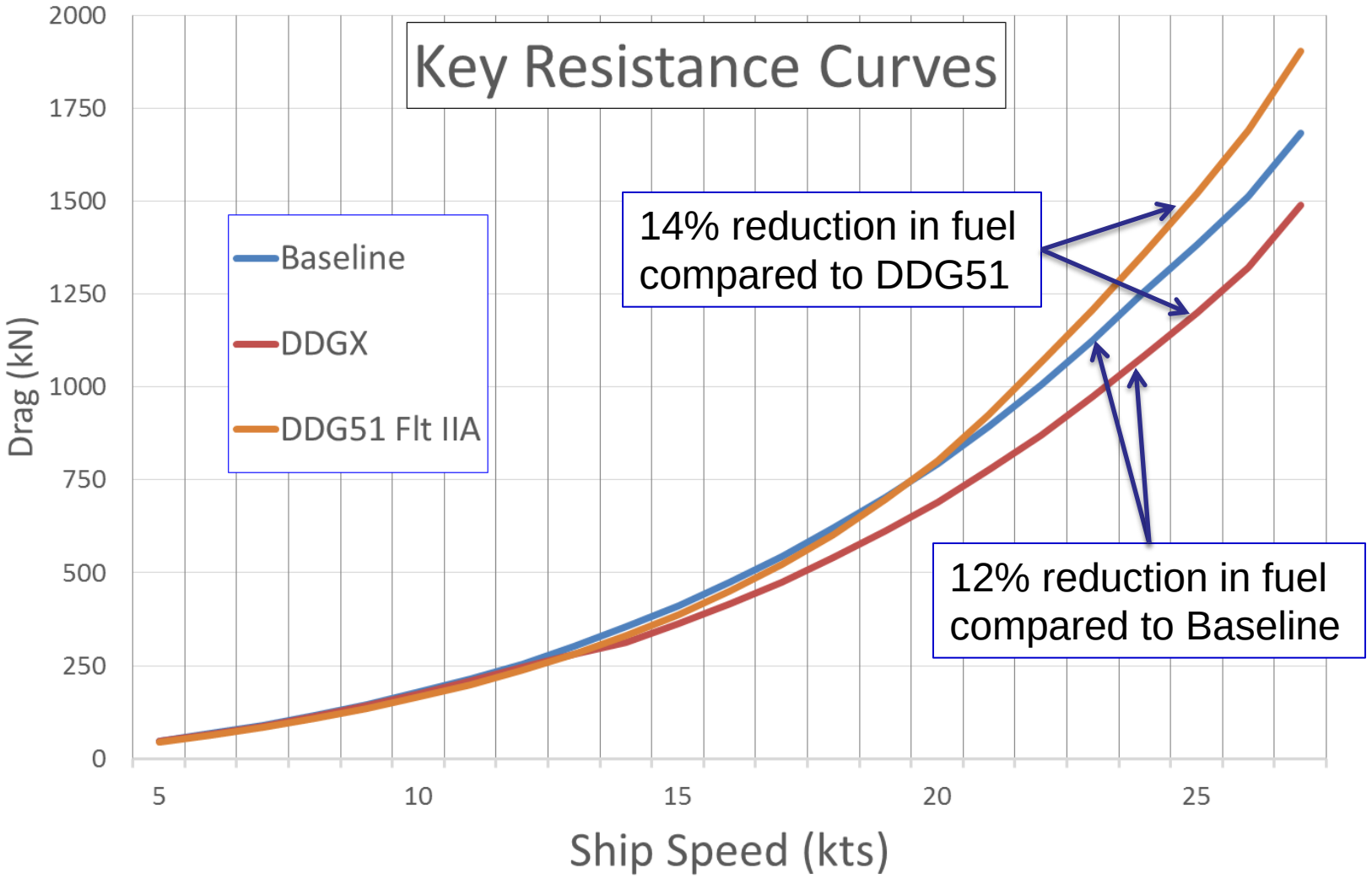
DDG51 Speed Time Profile

Center for Ocean Engineering
Naval Construction & Engineering Program
Department of Mechanical Engineering



Hullform Optimization

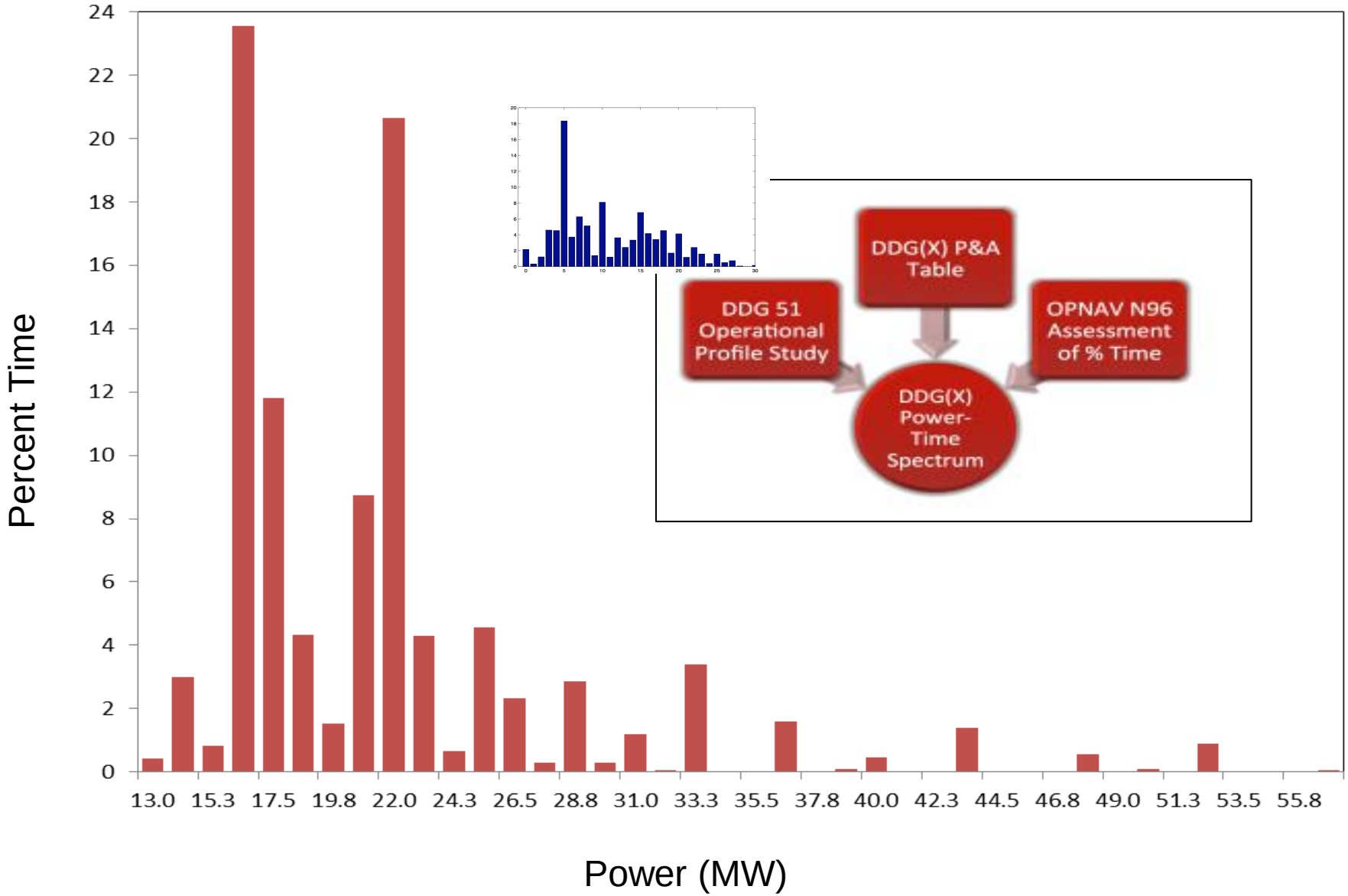
Center for Ocean Engineering
Naval Construction & Engineering Program
Department of Mechanical Engineering



Massachusetts Institute of Technology

DDGX Power-Time Profile

Center for Ocean Engineering
Naval Construction & Engineering Program
Department of Mechanical Engineering



Engine Configuration Selection

Center for Ocean Engineering
Naval Construction & Engineering Program
Department of Mechanical Engineering

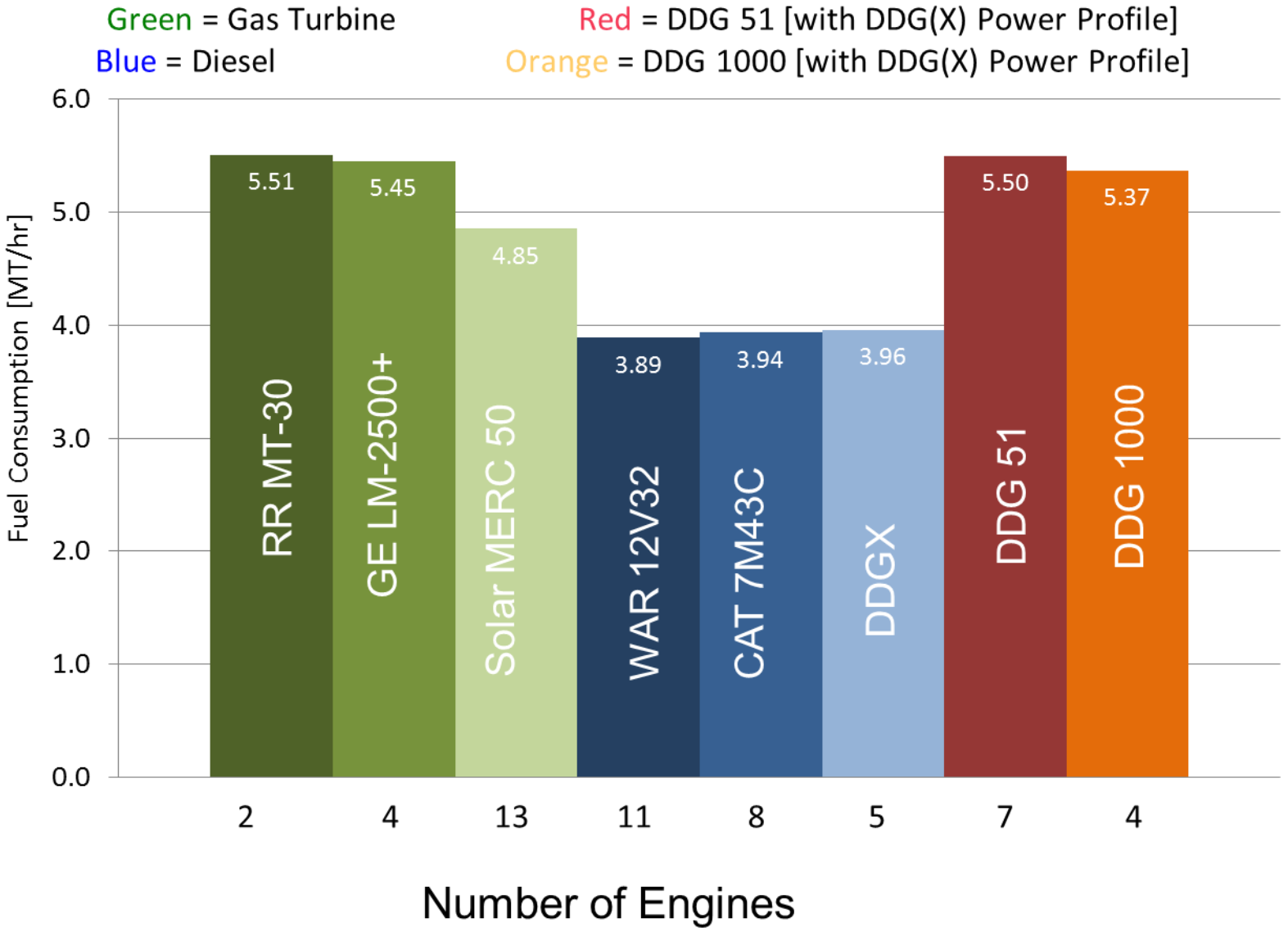
- **Problem: Select combination of engines to minimize fuel consumption across a given discretized *power-time spectrum***
- **MATLAB code created**
- **Inputs:**
  - 130+ engines from expansion and update of ASSET engine database
  - Over 10^{16} possible combinations!
- **Goal: to minimize fuel by matching engines to power-time profile and SFC curve**

Engine Selection

- Implemented IBM's CPLEX Optimizer (or in this case, minimizer)
- Code logic:
  - Chose given set of engines (vice computationally prohibitive comprehensive set) and allowed results to dictate next set of chosen engines in a genetic algorithm. i.e., are GT/GT combos best? GT/diesels?
  - Spectrum fuel minimization
    - For each power "bin", all possible power combinations were analyzed for net fuel consumption.
    - Each bin's lowest possible fuel consumption that met the power requirement was recorded and then eventually summed with the lowest fuel consumption from other bins to determine net power consumption summed across the spectrum
  - Process was iterated until results converged to a fuel consumption minimum…

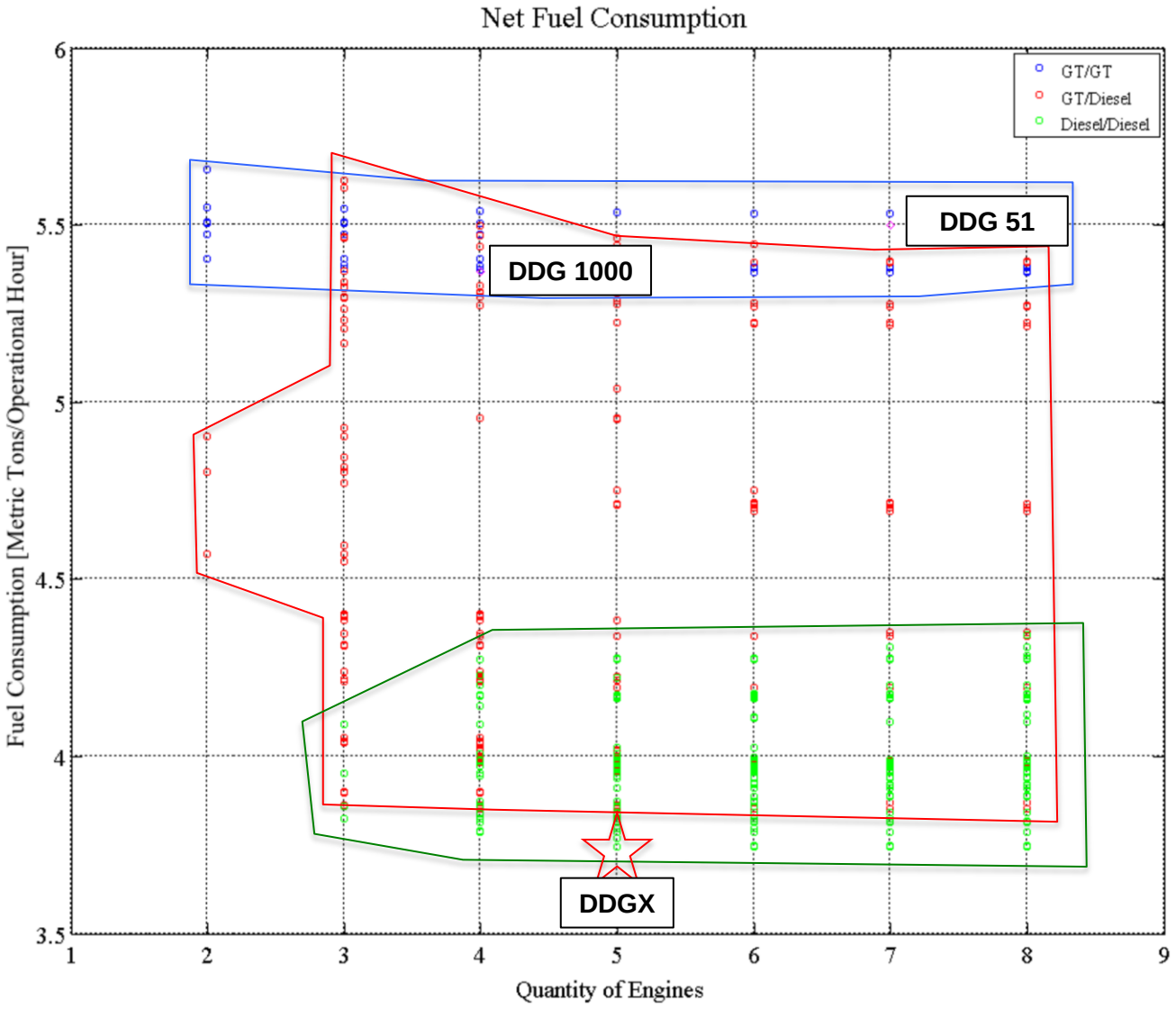
Sample of Code Results

Center for Ocean Engineering
Naval Construction & Engineering Program
Department of Mechanical Engineering



Engine Selection Results

Center for Ocean Engineering
Naval Construction & Engineering Program
Department of Mechanical Engineering

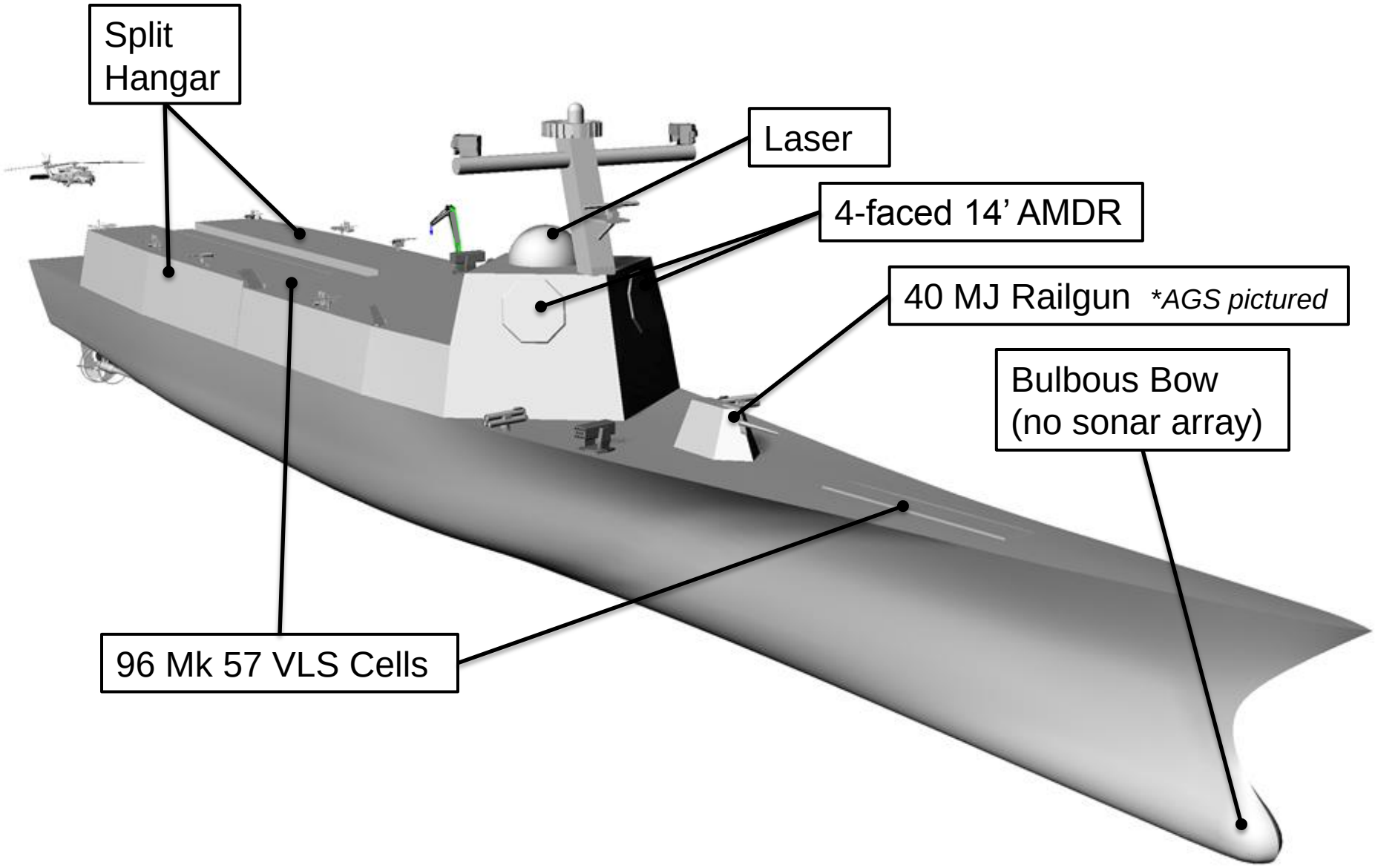


- Results pushed team to diesel engines
- Credit was given to fewer types and fewer total engines based on:
  - Maintenance
  - Weight
  - Size
  - Manpower
  - Supply chain
  - Training
- Engine selection plus optimal loading yields:

More than 30% fuel savings

The Ship

Center for Ocean Engineering
Naval Construction & Engineering Program
Department of Mechanical Engineering



Principal Characteristics

Center for Ocean Engineering
Naval Construction & Engineering Program
Department of Mechanical Engineering

Property	DDG51, Flt. IIA	DDG(X)	DDG 1000
LOA [ft]	510	580	610
Beam [ft]	66	66	81
Draft [ft]	26	25.5	27.6
Δ [MT]	9,000	12,900	15,000
V_{max} [kts]	30+	27	30+
Propulsion	Conventional	IPS	IPS
Engines	4 x GE LM2500 GTs, 3 x Allison 501 GTs	5 x Wärtsilä 16V38 Diesel Engines	2 x RR MT-30 GTs, 2 x RR-4500 GTs
Fuel Efficiency [MT/operational hour]	5.50*	3.90	5.37*

**Denotes usage of DDGX power-time profile*

DDG(X) Capabilities

Center for Ocean Engineering
Naval Construction & Engineering Program
Department of Mechanical Engineering

- **Major upgrades and changes:**
  - VLS upgraded to 96-cell Mk 57
  - 5” gun upgraded to railgun
  - Laser added
  - Primary radar upgraded to AMDR
  - Surface Electronic Warfare Improvement Program block 3
  - Maximum speed reduced to 27 knots
  - No hull-mounted sonar

- **Major impacts:**
  - Increased weight
  - Significant power demand increase
  - Seakeeping affected in high seas

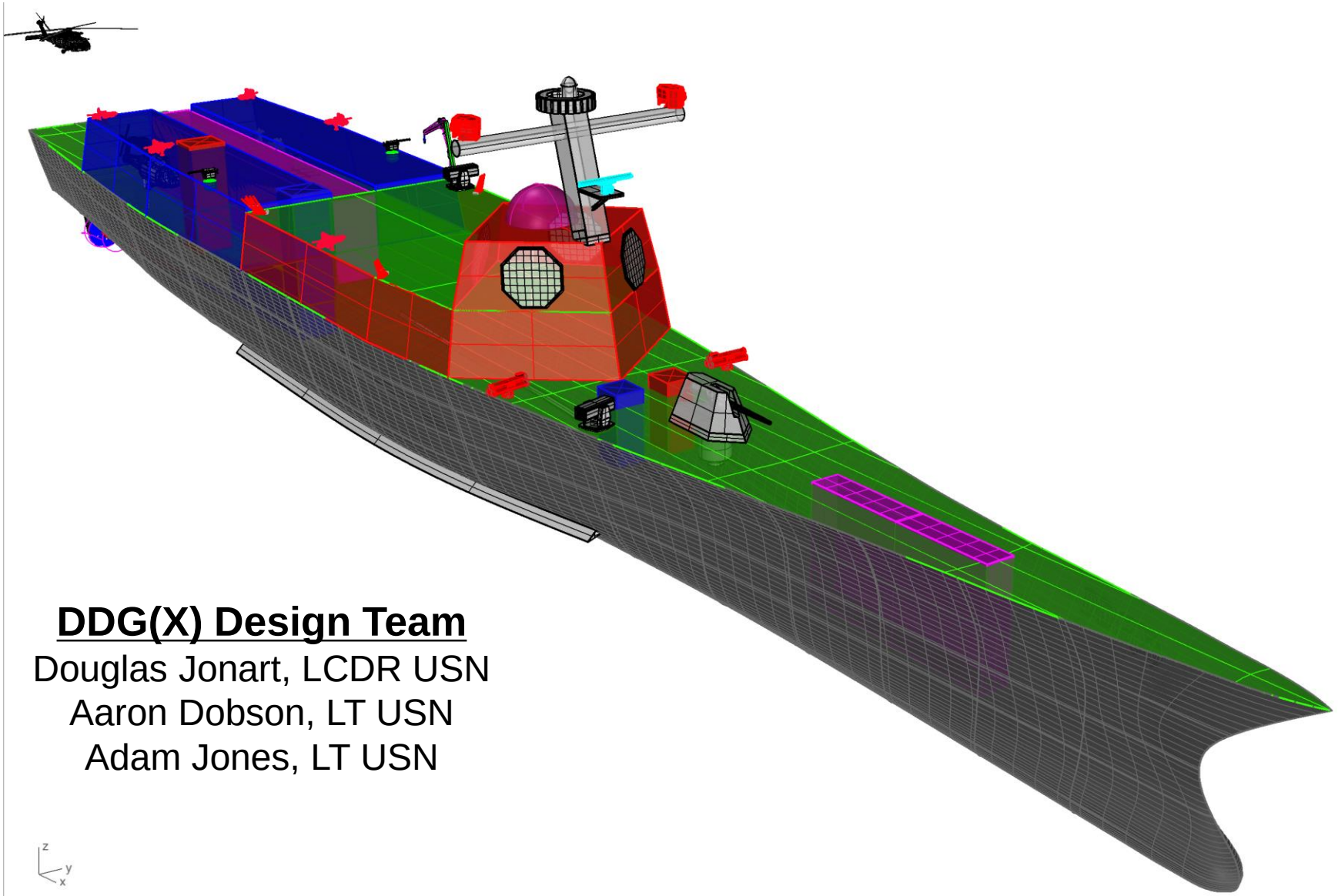
Summary

Center for Ocean Engineering
Naval Construction & Engineering Program
Department of Mechanical Engineering

- **By optimizing a hullform for efficiency, fuel consumption was reduced 14%**
  - Even over smaller DDG-51
  - Believe next iteration can improve seakeeping
- **Using improved engine selection technique and optimizing loading reduced fuel consumption by more than 30%**
- **Capability significantly improved**
  - At or above desires of operational Navy
  - IPS is the future even without railgun and laser

Questions and Wrap-Up

Center for Ocean Engineering
Naval Construction & Engineering Program
Department of Mechanical Engineering



DDG(X) Design Team

Douglas Jonart, LCDR USN
Aaron Dobson, LT USN
Adam Jones, LT USN