High Efficiency Microturbine with Integral Heat Recovery

Contract DE-EE 0004258

Capstone Turbine Corporation, Oak Ridge National Laboratory, NASA Glenn

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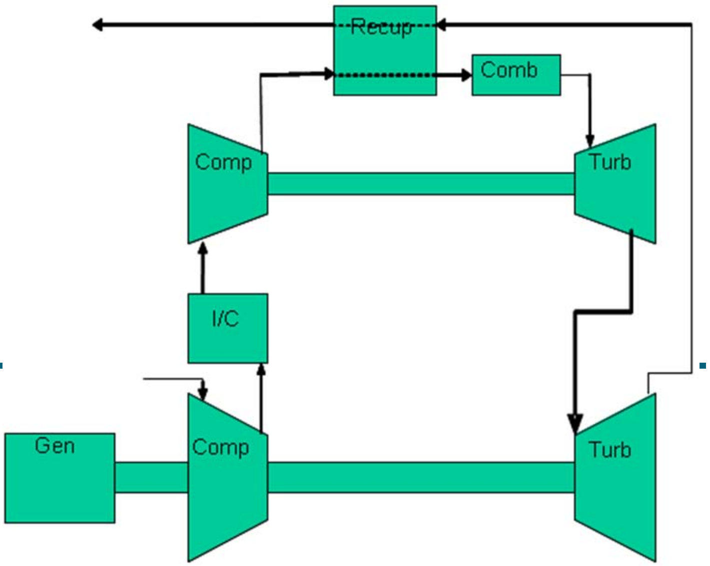
U.S. DOE Industrial Distributed Energy Portfolio Review Meeting
Washington, D.C.
June 1-2, 2011

C250 / C370 Engine – Capstone/DOE Program

- Current Technology at 33% efficiency
- Potential Products
  - C250 at 250kW and 35% Efficiency
  - C370 at 370kW and 42%+ Efficiency

- Key Technical Developments
  - Dual Property High Temperature Turbine
  - High Pressure Compressors & Recuperator – 11:1
  - Dual Generators – both LP and HP spool
  - Dual Spool Control Development
  - High Temperature Low Emissions Combustor
  - Inter Stage Compressor Cooling

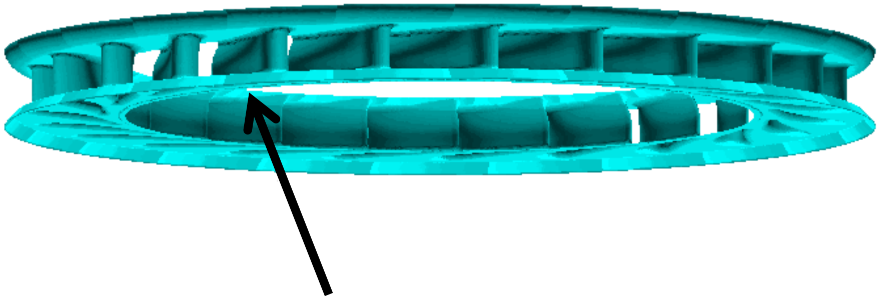


Thermodynamic Cycle for Proposed C370

Leading Edge High Efficiency Products

C250 Engine System

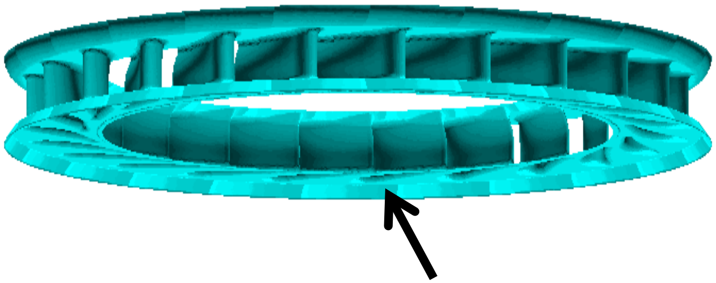
- C250 Development
  - Existing Technology
    - Turbine and recuperator common to current C200 product
    - Same rotor speed as C200
  - New Technology
    - 3D Aerodynamics
      - Compressor Diffuser
      - Turbine Nozzle
    - High Flow/PR Compressor
    - Engine Sealing Improvements
    - Generator Design with longer magnet & improved cooling
    - Integration as C370 LP rotor spool



Design for 270kW Nominal Power Output and 35% Efficiency

C250/C370 Engine Design

- Compressor Aero Design
  - 3D Aerodynamic Design - +2.2 % Component Efficiency
  - PR = 5.0 m = 3.6 lb/sec



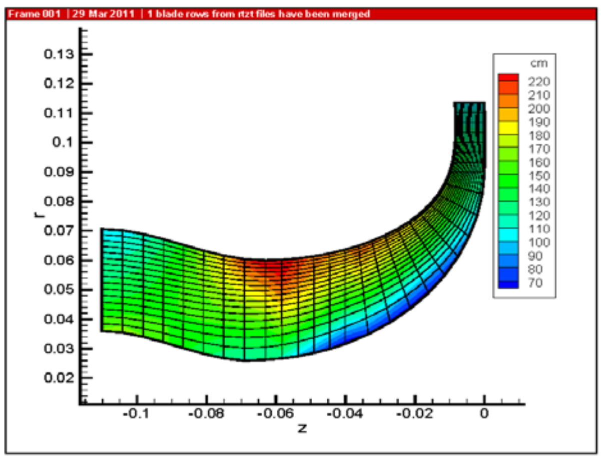
3D Aero – Curved Vanes

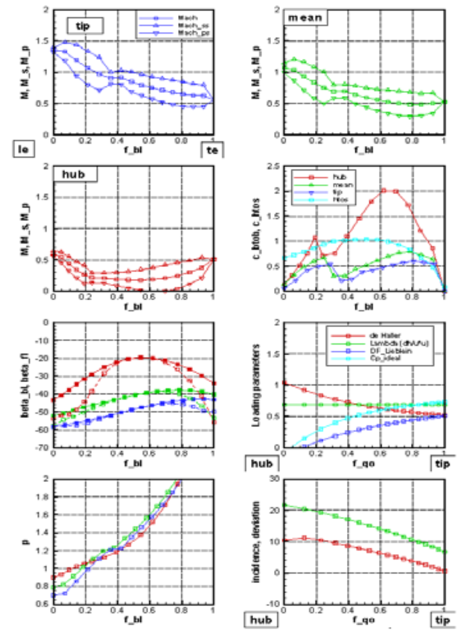
- Status
  - Design underway- Periodic reviews held
  - Design Completion – June, 2011

Design Release planned for June procurement of first components

C250 Aero Design Flowpath

Vista TF



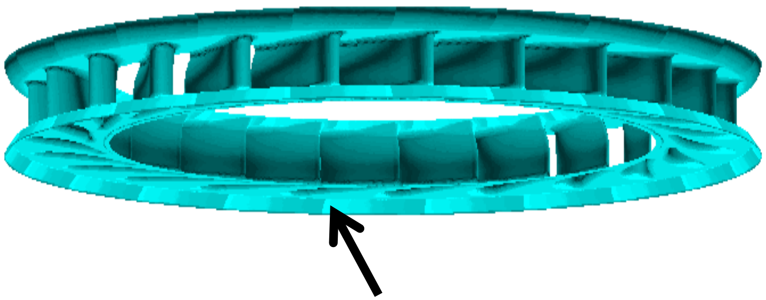


PCA ENGINEERS

Commercial-in-Confidence

C250 Engine Design

- Turbine Nozzle Aero Redesign
  - 3D Aerodynamic Design - +1.0 % Component Efficiency
  - C200 Mech. Interfaces

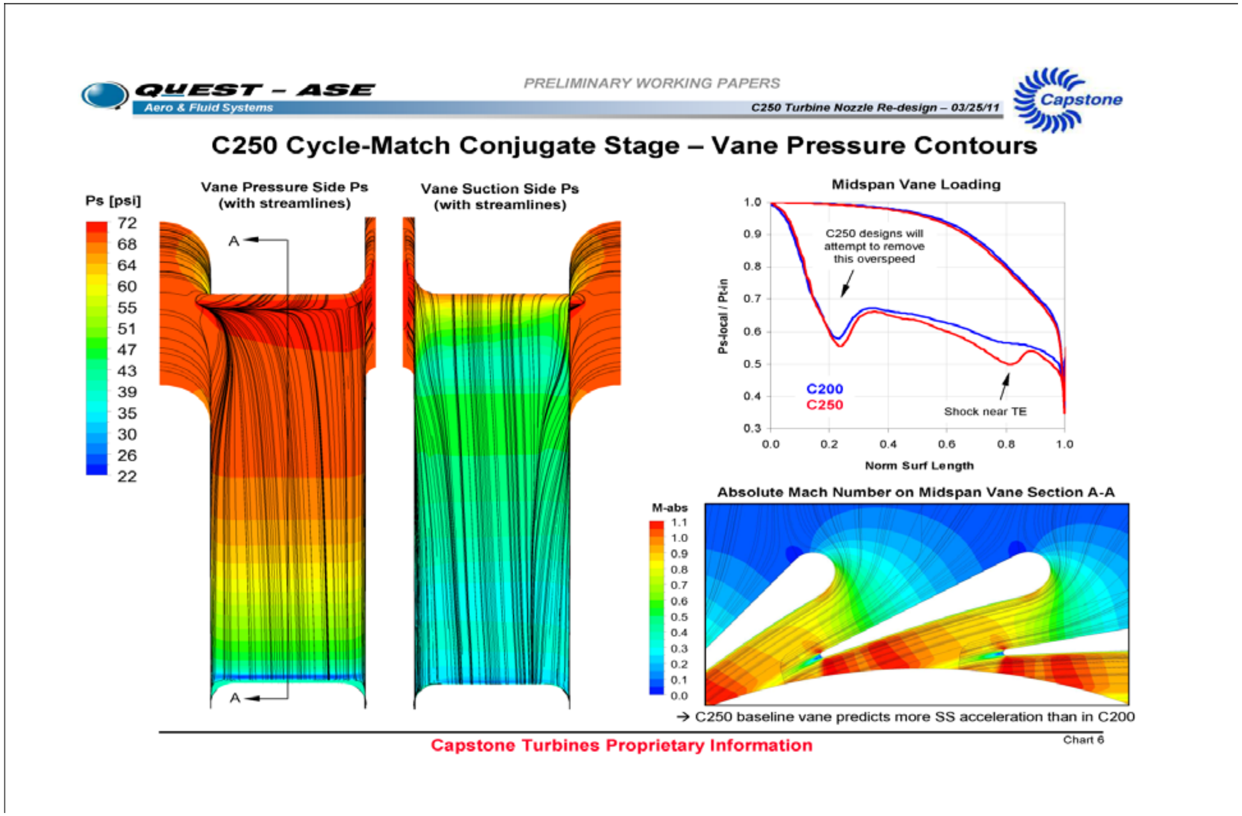


3D Aero – Curved Vanes

- Status
  - Design well underway- Periodic reviews held
  - Design Completion – July 2011

Design Release planned for June procurement of first castings

C250 Turbine Nozzle Aero Design



C250 Generator Design Concept

- C250 requires more powerful generator
  - Increase of 25% or more power capability
  - Simple growth version of C200 generator section involves a 125% length magnet shaft
    - Current C200 (100%) is 6.60”
    - Proposed C250 (125%) is 8.25”
  - Larger diameter magnet violates magnet design stress requirements at 60 krpm, leading to potential for magnet cracking
- Longer Magnet Design Validation
  - Critical Speed of Magnet Shaft will be lower
  - Need rig testing to validate Critical Speed margin

Oak Ridge National Lab Workscope

- *The C370 HP turbine utilizes a radial turbine wheel*
- *Approximately the same size and geometry as the C65 turbine wheel (~5.5" dia.)*
- *Current C65 turbine wheel is MAR-M-247*

- *MAR-M-247 is not feasible for the C370 HP wheel due to the higher rotor inlet temperature*
- *Options for the high-temperature wheel:*
  - *Multi-alloy metallic wheel*
  - *Ceramic (Silicon-Nitride) wheel*

NASA Workscope

- NASA responsibilities: Facilities, test journals, PS400 solid lubricant coating, labor
- Capstone responsibilities: Bearings and other required hardware

NASA SOW:

Task 1. Develop misalignment guidelines to lower fabrication costs

a) Approach: Impose a known misalignment and evaluate bearing performance

b) Test Rig(s): Rotor simulator test rig, Low speed foil bearing test rig

Transition and Deployment

Desirable Attribute	Importance to	
	End Users	Government
Lower Operating Costs	●	○
Increase Security of Power	⊙	○
Reduce Greenhouse Gas Emissions	○	●
Increase Energy Independence	○	●
Reduce Criteria Pollutants	○	⊙
Improve Fuel Economy	○	⊙
Ensure US Leadership	○	●

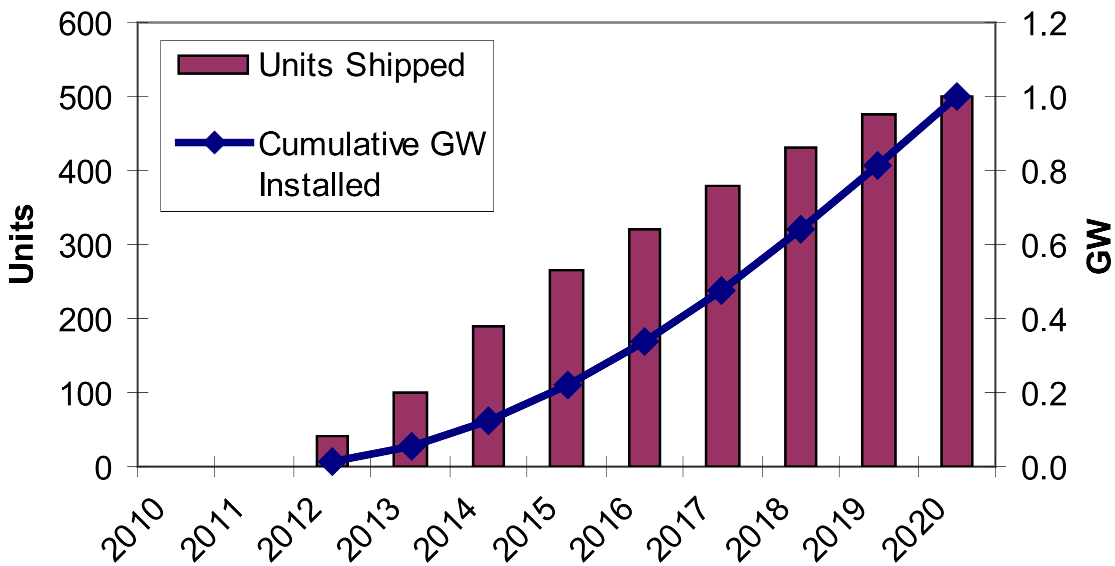
- Technology advantage can be sustained using
  - ❑ Patent Protection (Capstone has 100 worldwide today)
  - ❑ Market Leadership (Capstone has worldwide distribution)
  - ❑ The Right Incentives (need Government support)

Transition and Deployment

End User	Application	Key Attributes
Commercial (Hotels, Office, Retail) Small Industrial Facilities	CHP/CCHP*	Efficiency, Availability
Electric Utility	Peak Power	Availability, Efficiency
Oil & Gas Production	Remote Power	Stand Alone Capability
Data Centers / Telecom Critical Industrial Processes	Uninterruptible Power	Availability, Efficiency
Waste Water Treatment Plants Farms with Anaerobic Digesters	Renewable Fuel with CHP	Emissions, Efficiency
Vehicle OEM's	Series Hybrid Drive Systems	Efficiency, Emissions

Measure of Success

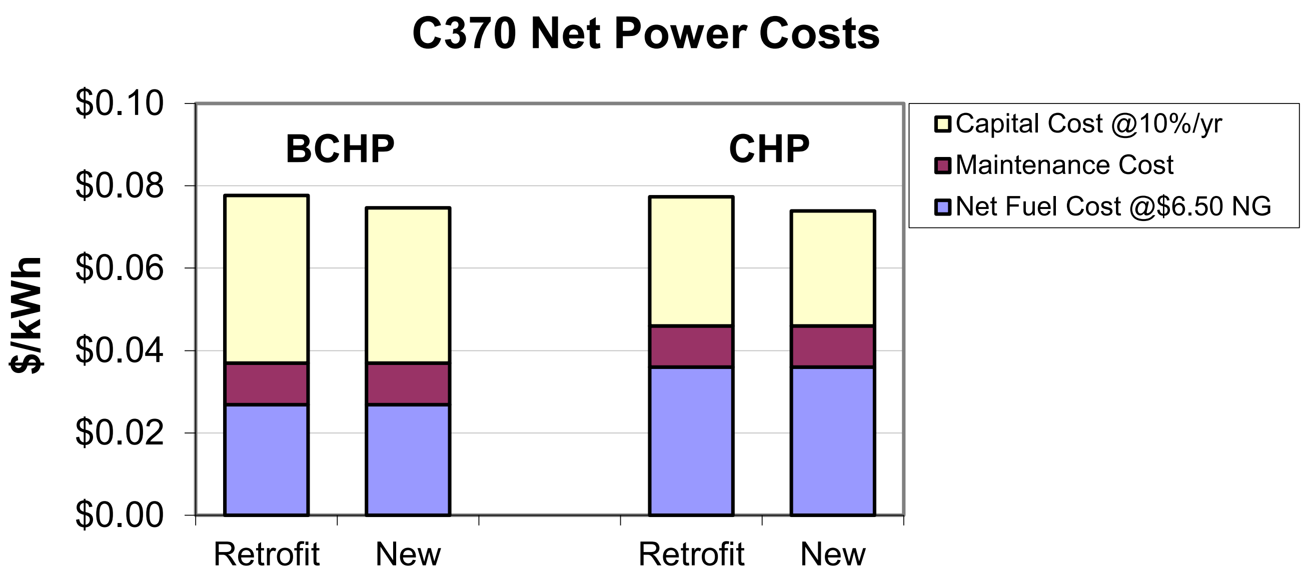
- US Production Opportunity:
  - Total C370 Market ~ AMTS Market = 31.3 GW
  - Conservative C370 Sales Projections ~ 3% of Total Potential



- US Leadership Opportunity:
  - 1,200 new or retained jobs
  - Retain worldwide technology advantage

Benefits

- Example Operating Costs



- Results in Significant Economic Market Potential

State	Economic Market Potential		
	Retrofit MW	20-Year New MW	Total MW
California	1,034	790	1,824
Texas	598	408	1,006
New York	532	352	883
New Jersey	408	264	671
Illinois	330	304	634
Connecticut	281	191	472

Benefits

- Energy & Environmental Benefits by 2020

Energy or Emissions Attribute	Annual Reduction
Fuel Consumption	15.4 GWh/year or 526 million Therms/year
NOx	8.8 Tons/year
CO2	2.8 Million Tons/year
Assumptions: C370 uses natural gas and is 42% efficiency with 85% total CHP efficiency, 1GW installed operating 8,000 hours/year with NOx of .14lb/MWh. Comparison is to getting electricity from the average US grid at 33% efficiency with 1.79 lb/MWh NOx and 1,300 lb/MWh CO2, and hot water from a boiler that is 80% efficient with NOx of .23lb/MWh using natural gas fuel input.	

Commercialization Approach

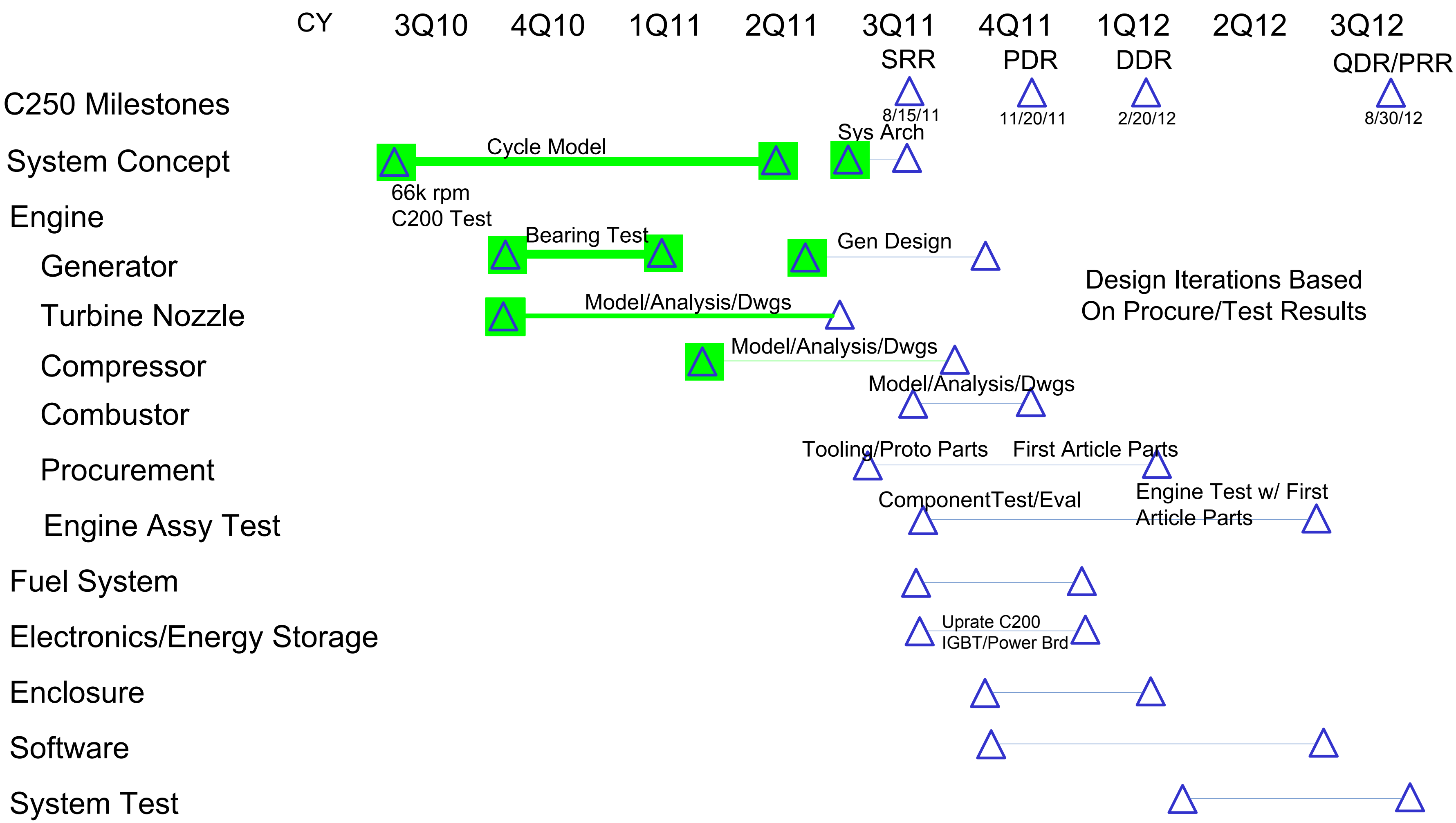
- Certify to UL, IEEE, CE and other Standards
- Train Sales & Service for Proper Support
- Utilize Capstone's Existing Distribution Channels
- Quantify Economic/Environmental Benefits
- Promote using Trade Shows/Conferences
- Develop Case Studies/White Papers/Videos
- Leverage Government Incentives/Rebates

Project Management & Budget

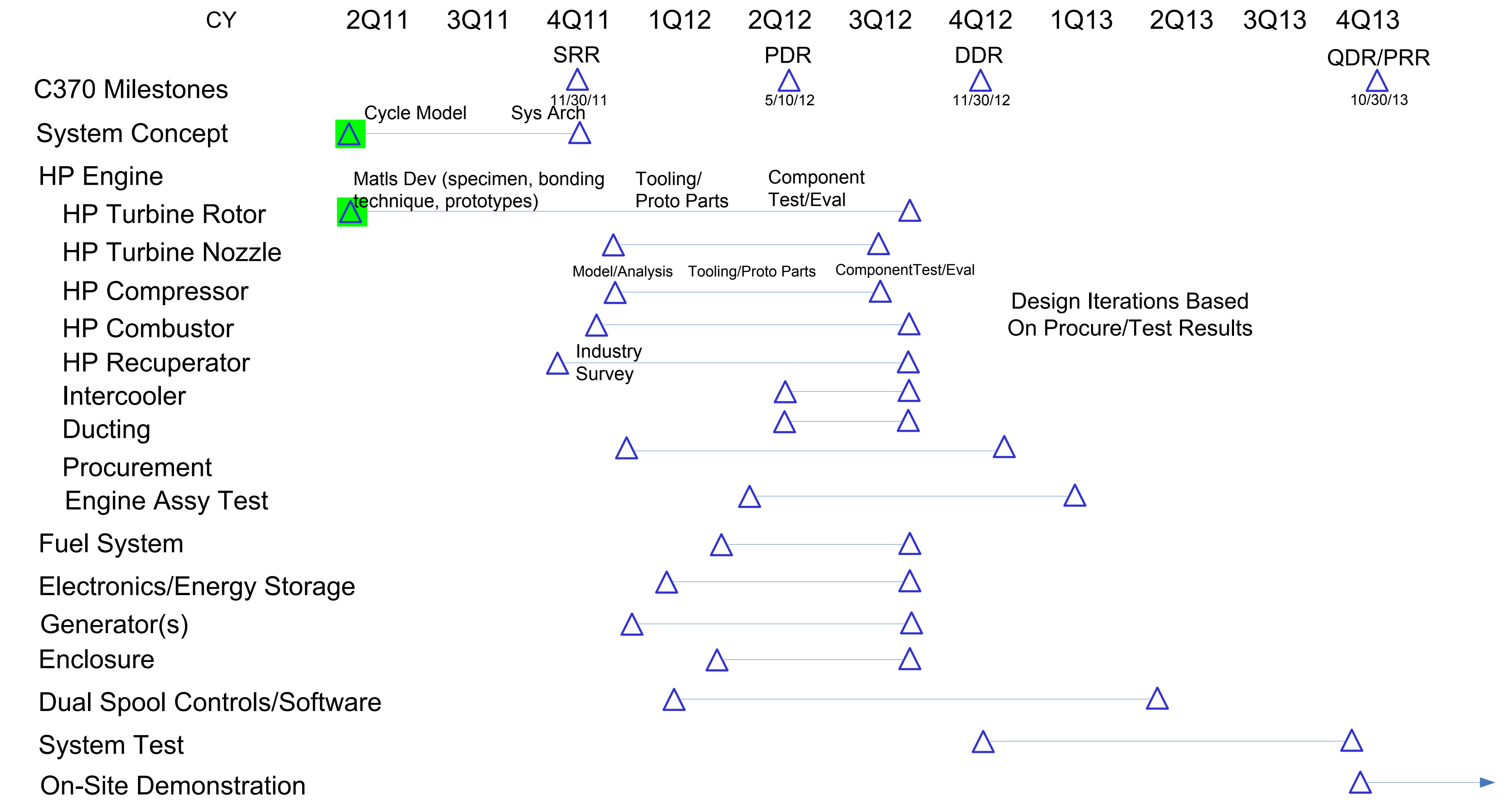
- Project task and milestone schedule
  - Schedule Performance - Earned Value will be measured against Planned Value.
    - Cost Performance
      - Earned Value vs Actual Cost
      - Unit cost model vs costed BOM

Project Budget				
	FY11	**FY12**	**FY13**	**FY14**
DOE Investment (CPST+ORNL/NASA)	775k+260k	2000k+250k	1255k+250k	150k+60k
Cost Share	1010k	5370k	5000k	1000k
Project Total	2045k	7620k	6505k	1210k

C250 Schedule



C370 Schedule



Upcoming Design Activity

- ***C250 Engine Design***
  - ***Bearing housing & shroud-line definition***
  - ***Compressor Impellor Stress & Aeromechanical Analysis Validation***
  - ***Nozzle and Compressor Drawing Release***

- ***C370 Combustor Conceptual Design***
- ***C370 Turbine Rotor Design Concepts***

- ***First C250 Engine Test in October 2011***

Questions?