CSP Technology Workshop

Molten Salt Power Towers

Hamilton Sundstrand
A United Technologies Company

Presented by: Dale Rogers

March 7th 2007

Pratt & Whitney
A United Technologies Company

Discussion Topics

- Rocketdyne Power Systems Heritage
- Current Organizational Overview
- Molten Salt Power Towers
  - System Description
  - Technology / Commercial Readiness
  - Current Status / Path Forward
  - Suggestions for DOE R&D Support

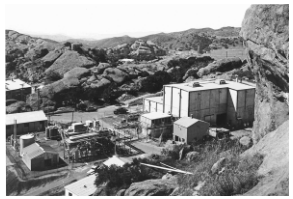
Rocketdyne Power Systems Heritage

1950 1960 1970 1980 1990 2000 2005

Nuclear

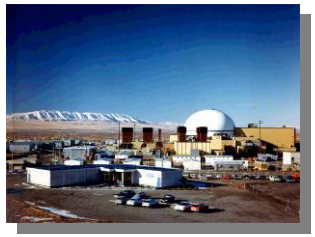
Fossil

Solar



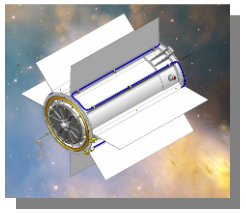
First Nuclear Power on US Grid

SNAP 10A: First Nuclear Reactor in Space



Fast Flux Test Facility (FFTF)

Test Facility & Cogeneration Plant



Radioisotope Power Systems (MMRTG)

Gasification Systems

Hydrogen Generators

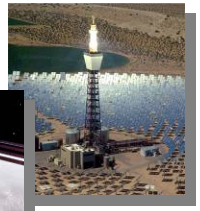
Gasification Pilot Plant

Fluidized Combustion

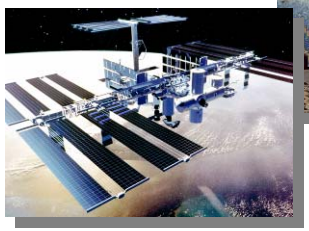
Kalina Plant

Rocket Engine Technologies

Solar 1 & 2



Commercial Solar Power



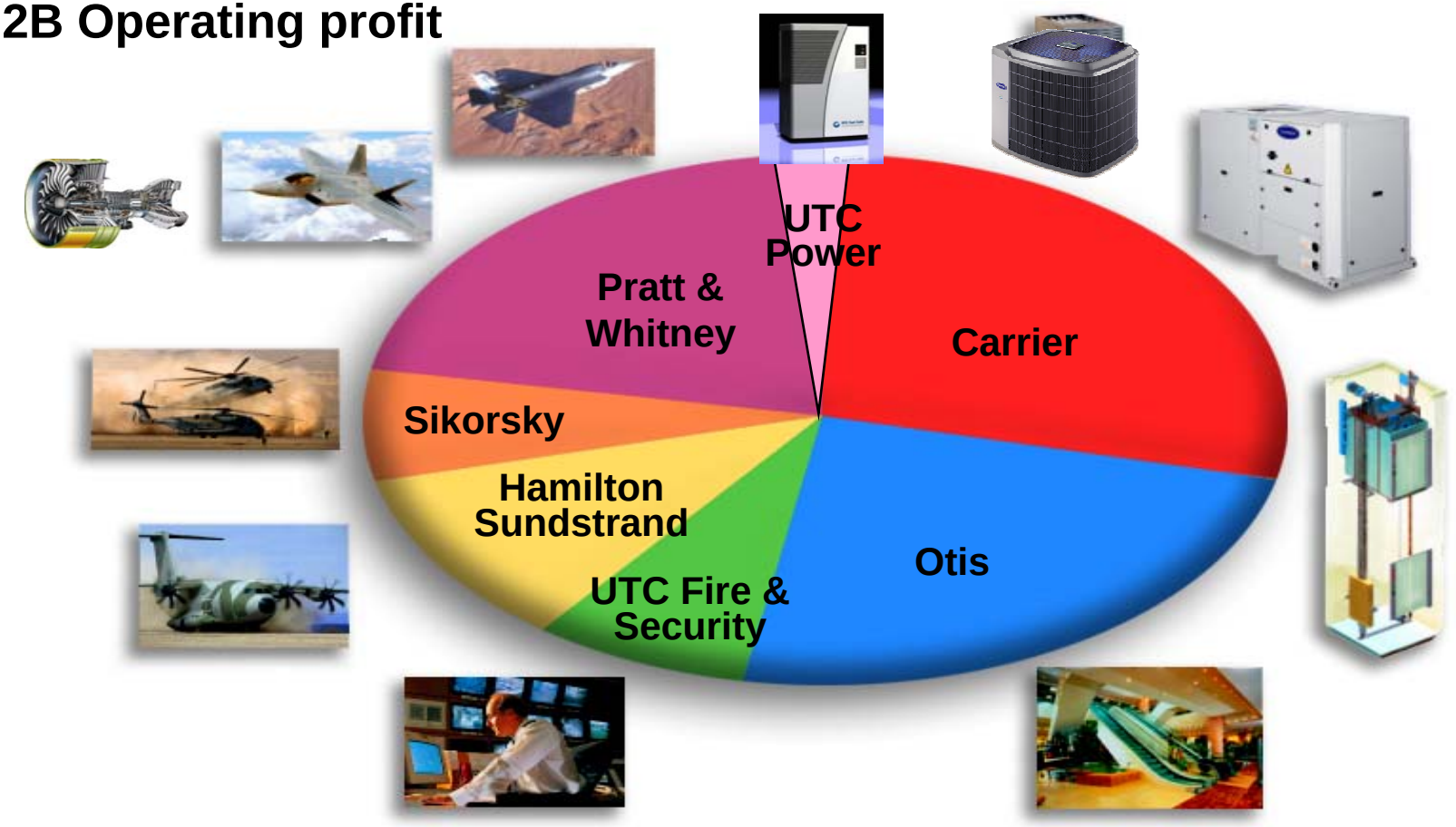
Space Station Power System

Hamilton Sundstrand
A United Technologies Company

United Technologies Corporation (UTC)

- $42.7B Sales (2005)
- $5.2B Operating profit

- > 200,000 employees
- Operating in 180 countries



United Technologies Corporation (UTC)

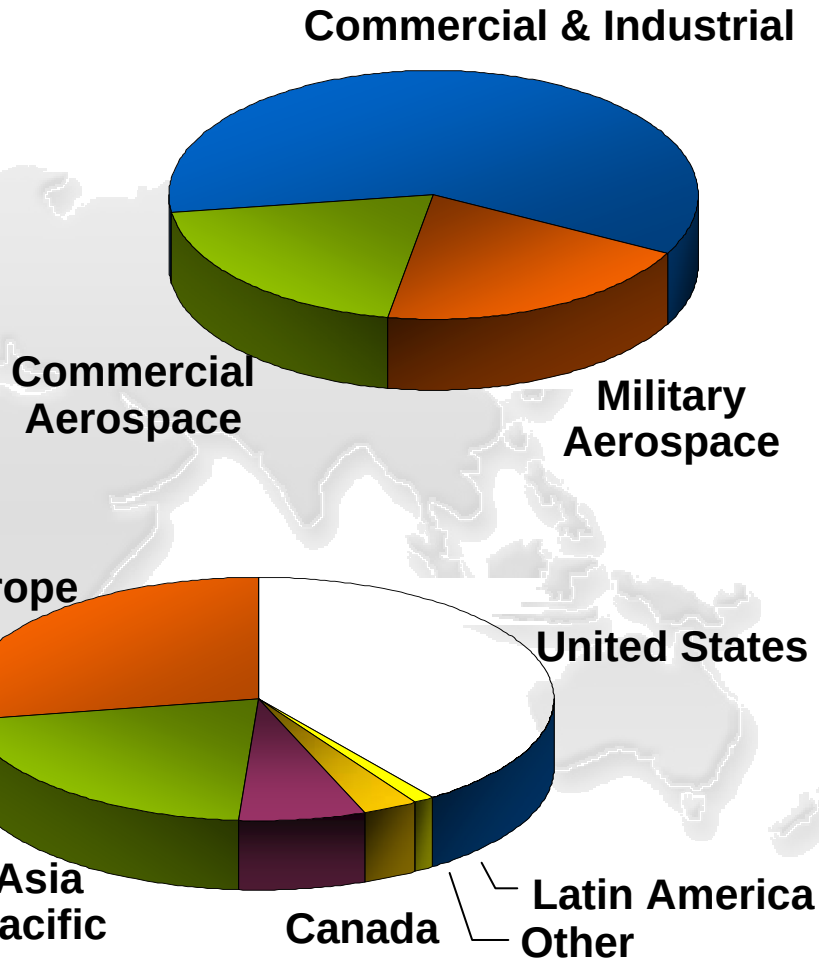
Segment Revenues

60%
Commercial

28%	Carrier
24%	Otis 24%
8%	UTC Fire & Security

40%
Aerospace

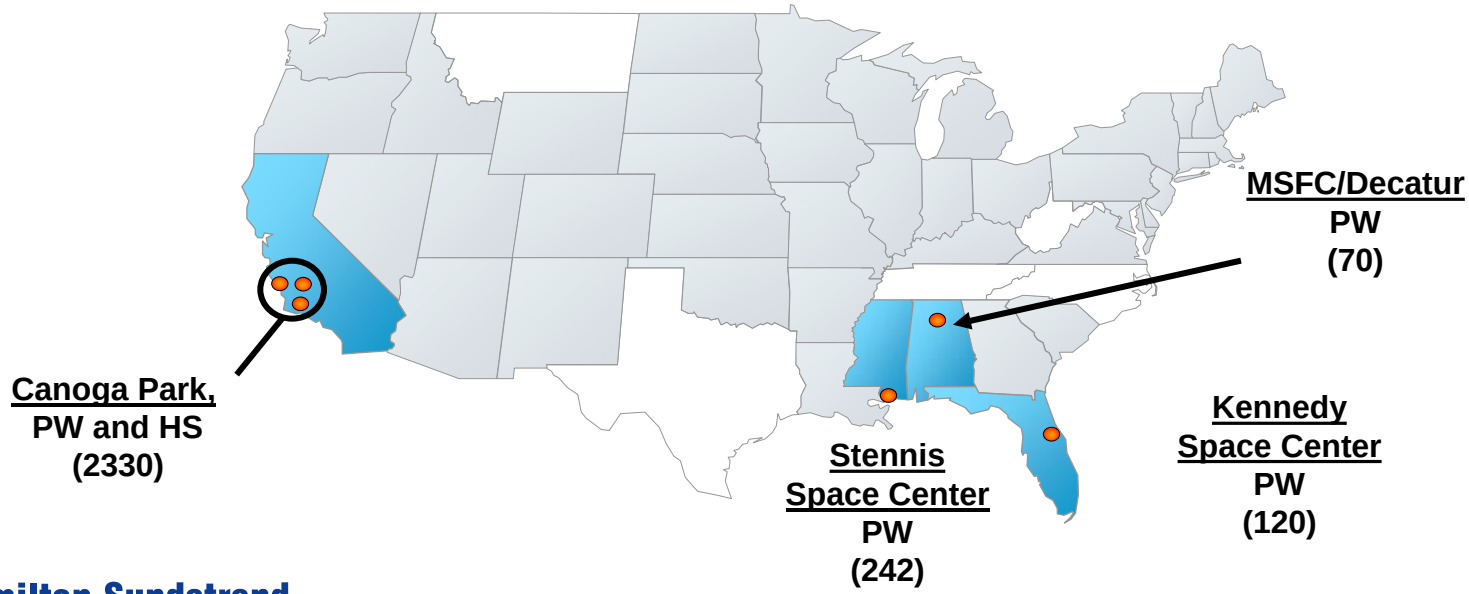
11%	Hamilton Sundstrand
22%	Pratt & Whitney
7%	Sikorsky



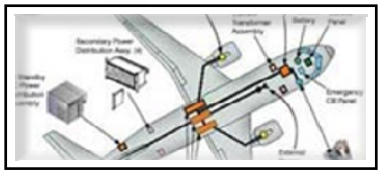
Hamilton Sundstrand
A United Technologies Company

Rocketdyne Propulsion & Power

- **UTC Pratt & Whitney acquired Rocketdyne Propulsion & Power from Boeing**
  - **August 2005**
  - **Pratt & Whitney Rocketdyne, Inc**
    - **Combined P&W Space (West Palm Beach) and Rocketdyne *Propulsion***
- **Hamilton Sundstrand given responsibility for Advanced *Power* systems**



Rocketdyne Energy Systems Across UTC

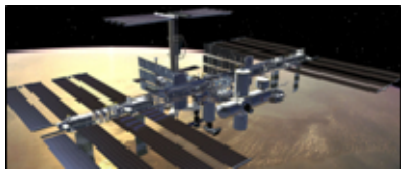


Hamilton Sundstrand

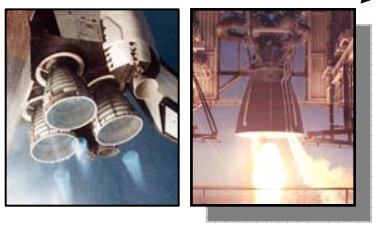
UT Research Center

UTC Power

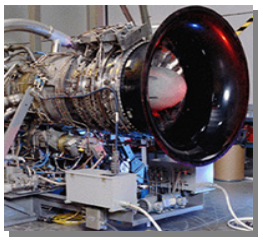
Pratt & Whitney



Space Land Sea
Rocketdyne



Pratt & Whitney
Rocketdyne



Power Systems

Terrestrial Programs

Technology
Demonstrated

Building Gasification
Demonstrator on
DOE contract

H_2 Generator
in test

Hamilton Sundstrand
A United Technologies Company

Molten Salt Power Tower
Description of Plant Operations

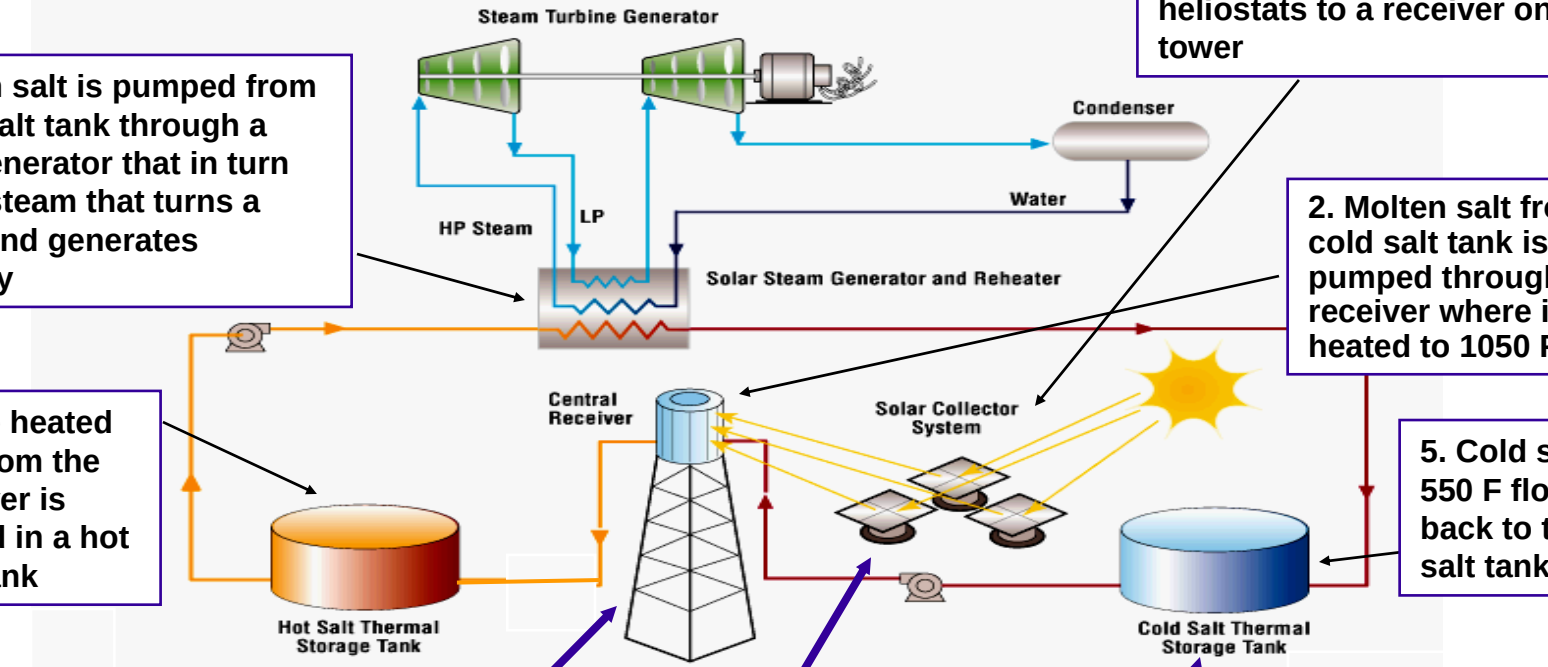
1. Sunlight is concentrated and directed from a large field of heliostats to a receiver on a tall tower

2. Molten salt from the cold salt tank is pumped through the receiver where it is heated to 1050 F

3. The heated salt from the receiver is stored in a hot salt tank

4. Molten salt is pumped from the hot salt tank through a steam generator that in turn creates steam that turns a turbine and generates electricity

5. Cold salt at 550 F flows back to the cold salt tank



Central Receiver

Power Tower

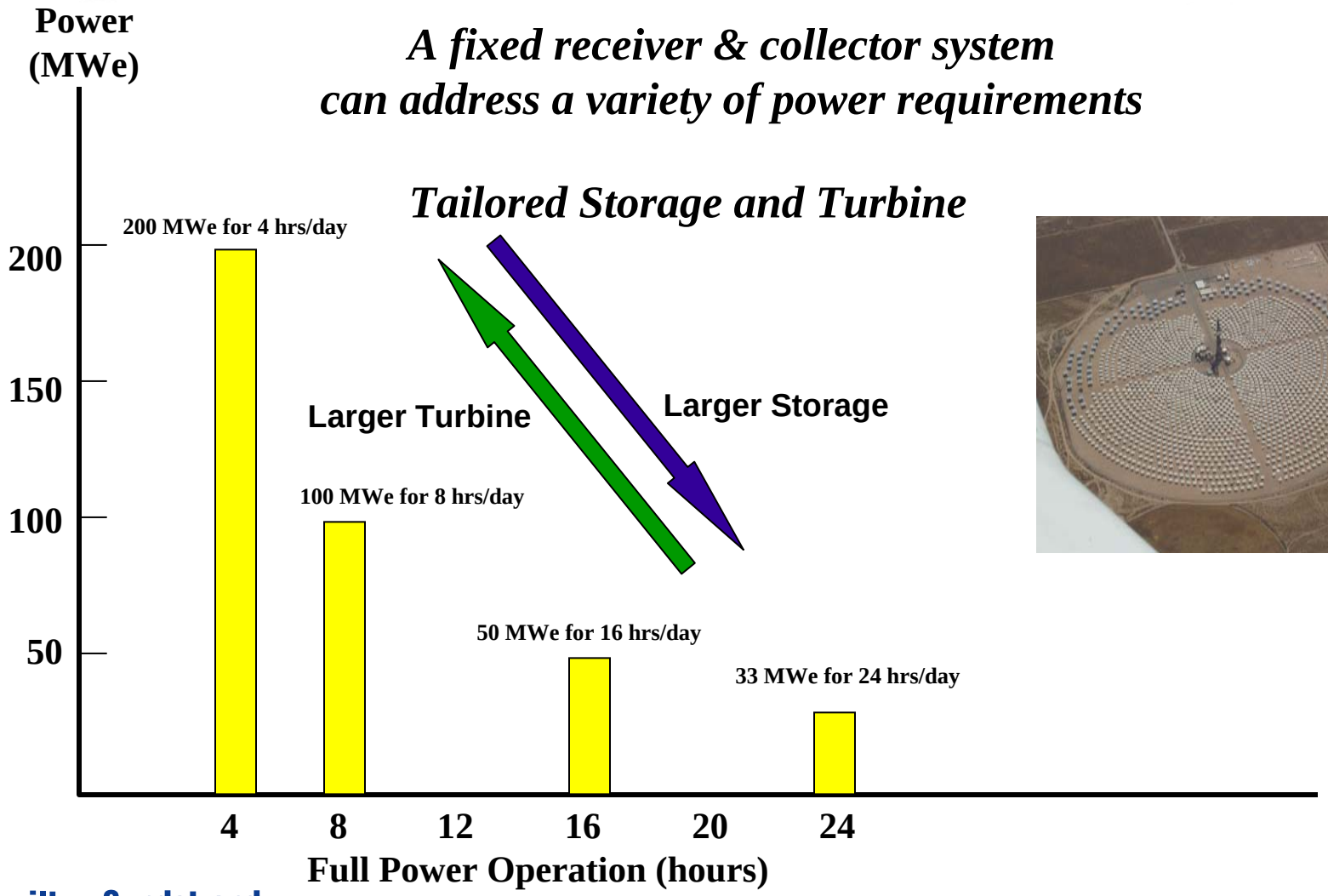
Heliostat

Storage Tanks

Power Tower Plant Options
Flexibility to Meet Specific Customer Needs

A fixed receiver & collector system can address a variety of power requirements

Tailored Storage and Turbine



Hamilton Sundstrand
A United Technologies Company

Power Towers Successfully Demonstrated

Solar Two Validated Design, Performance, & Operation

Technology Demo

1994-1998

Barstow, California

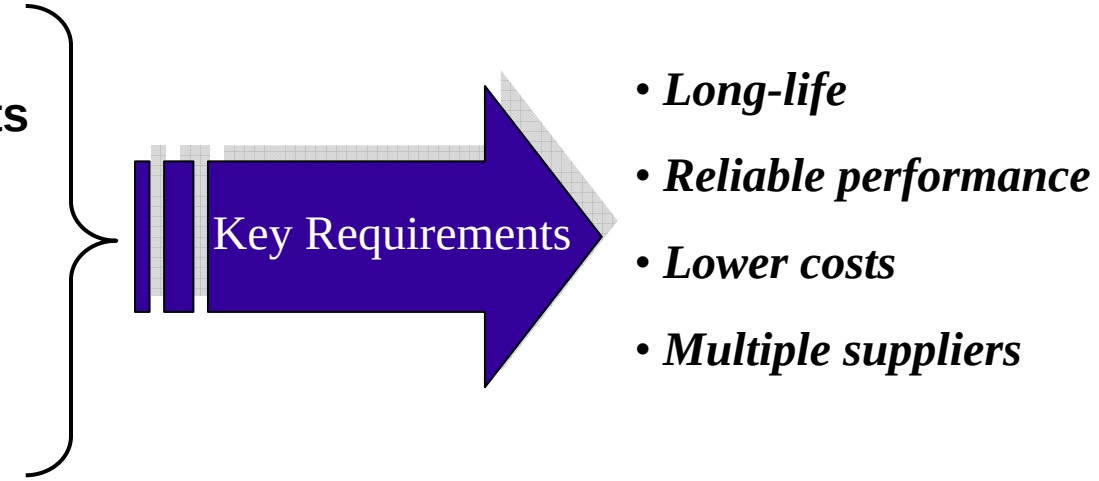
- **Plant Dispatchability**
  - **Demonstrated electric power 24 hr/day**
- **Power Output**
  - **Exceeded performance targets**
- **Receiver Performance**
  - **Exceeded prediction (receiver efficiency 88%)**
  - **Achieved design temperatures, flow rates, & pressure drops**
  - **Demonstrated “normal” & “off-normal” operations**
- **Pump Performance**
  - **Demonstrated full-flow at design pressures**
- **Thermal Storage**
  - **Demonstrated high efficiency storage**

Current Status & Path Forward

- **Technology successfully demonstrated**
  - **Key attributes - thermal storage / dispatchability**
- **Ready now for commercial market entry**
  - **Environment has changed since Solar 2 demonstration**
    - **External - global awareness of & interest in CSP**
    - **Internal – UTC willingness to pursue new market area**
  - **Leveraging Solar 2 “lessons-learned” to manage project risk**
    - **Limit to evolutionary improvements for early projects**
    - **Continue parallel R&D for downstream project improvements**
  - **Leveraging state / federal / global mandates & incentives**
- **Key strategic alliances being developed**
  - **Leveraging strengths to develop world-class team**

Suggestions for DOE R&D Support

- **Continuous improvements to enhance project attractiveness**
  - **Enhance technical performance**
  - **Reduce project risks / uncertainties**
  - **Reduce capital cost**
  - **Reduce O&M cost**
- **Emphasis on major cost / risk drivers**
  - **Heliostats**
  - **Molten salt components**
    - **Pumps**
    - **Valves**
  - **Molten salts**
  - **Materials**
  - **Coatings**



Summary

- **Power Tower Technology**
  - **Successfully demonstrated at Solar 2**
  - **Achieved continuous improvements post-Solar 2**
  - **High efficiency heat retention enables power dispatch when needed**
- **UTC – Rocketdyne Power**
  - **Developing key strategic alliances and actively pursuing power projects**
  - **Leveraging mandates & incentives for early projects**
  - **Investing in parallel R&D to enhance future market attractiveness**

Collaboration with DOE / National Labs can facilitate near-term project success and long-term growth