



INFINIA

FOCUS YOUR ENERGY

30 kW Maintenance Free Stirling Engine for High
Performance Dish Concentrating Solar Power

Contract No. DE-FC36-08G018032

February 10, 2010

Please silence your cell phones

Objectives

- Reduce solar LCOE through development of 30 kW maintenance-free multi-cylinder free piston Stirling engine
- Provide prototype engine preliminary design and preliminary LCOE estimate by the end of Phase I
- Complete final design, fabricate and demonstrate 30-kW laboratory prototype engine by the end of Phase II
- Deliver and field test a prototype 30-kW Stirling engine on sun by the end of Phase III

Phase I	Phase II	Phase III
<ul style="list-style-type: none"> • Develop a preliminary design of the 30-kW multi-cylinder engine • Develop preliminary manufacturing cost analysis • Verify LCOE impact • Determine residual technical barriers and revise the Phase II and 3 task details 	<ul style="list-style-type: none"> • Complete detailed design of 30-kW engine • Fabricate and assemble 30-kW prototype engine • Evaluate engine performance • Refine cost analysis 	<ul style="list-style-type: none"> • Field test engine and supporting components • Demonstrate 30-kW engine on an existing dish • Validate engine producibility • Verify production cost • Develop Production/Business Plan

Infinia Free Piston Stirling Engine Operation

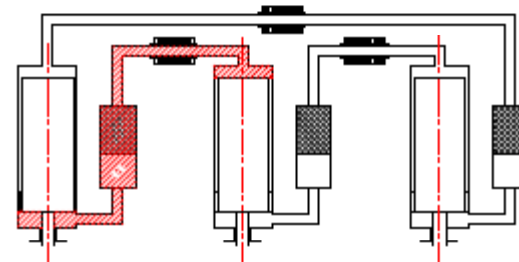
Through December 2009	10 watt (National Security)	55 watt (NASA)	350/450 watt (comm'l)	1 kW (comm'l)	3 kW (comm'l Solar)	Total
Units	10	30	20	14 (Infinia) >300 (Licensees)	110	>420
Longest test (hrs)	100,000	50,600	30,000	25,000	1,800	N/A
Cumulative test time at Infinia	178,500	30,000	24,000	52,000	5,000	289,500
Cumulative test time at Clients	163,000	198,000	51,000	150,000	19,200	581,200
Total Test Time	341,500	228,000	75,000	202,000	24,200	870,700

Stirling Engine Type Characteristics

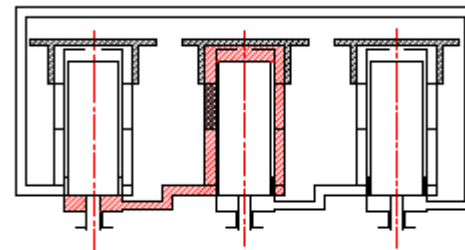
- Free-Piston Engine (FPSE)
 - Elegant mechanical simplicity – low parts count
 - No rubbing parts + flexure bearings → **long life, high reliability**
 - Single-cylinder with displacer → **complex dynamic analysis**
- Kinematic Engine
 - Single and multi-cylinder options, experience to 265-kW
 - Double-acting multi-cylinder has high power density
 - Oil-lubricated crankcase with crankshaft, connecting rods etc.
 - Sliding seals fundamentally limit life and reliability
- Multi-Cylinder Free-Piston Engine
 - Combines best features of free-piston and kinematic
 - Avoids limitations of both
 - Improved power density
 - No Displacer to require sophisticated FPSE tuning

Multi-Cylinder Free Piston Stirling Engine

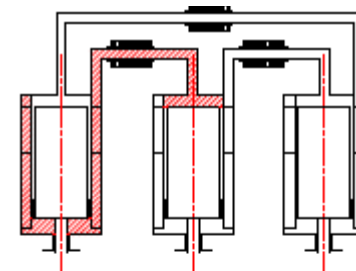
- Three different basic configurations are available.
- Annular construction with an integral hot heat exchanger chosen
- Minimizes engine footprint and complexity
- Leverages Infinia core competency



CANNISTER / EXTERNAL HOT HX



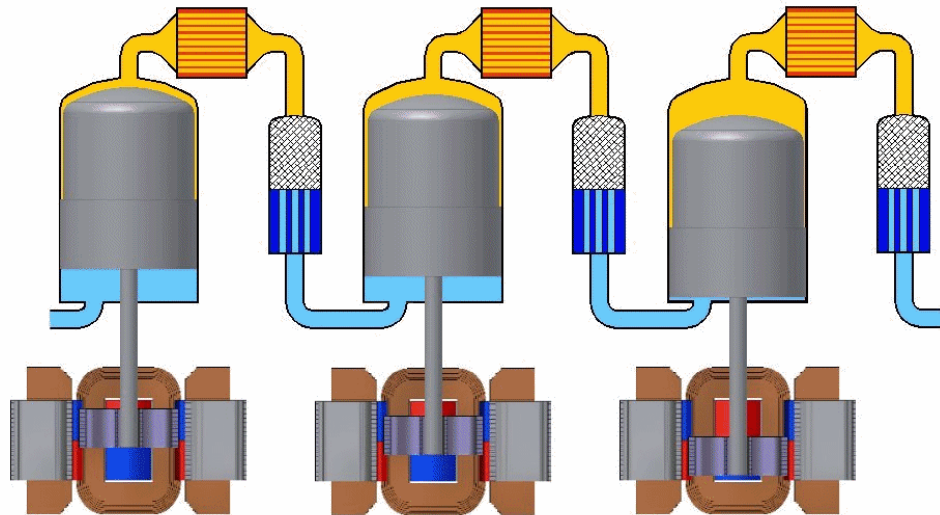
ANNULAR / INTEGRAL HOT HX



ANNULAR / EXTERNAL HOT HX

Multi-Cylinder Free Piston Stirling Engine Animation

- Double acting, free piston design
- No displacer, connecting rods, cams, etc.
- Thermodynamic cycle forces piston phasing (120° for 3 cylinders)

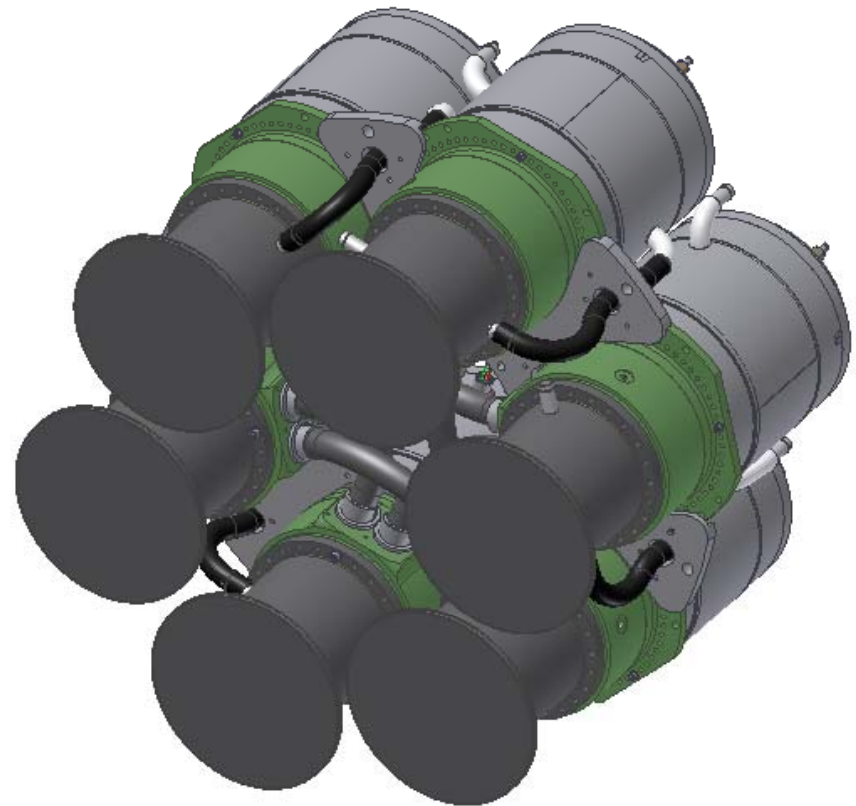


Phase 1 Background

- Developed a preliminary design of the 30 kW multi cylinder engine
 - Heater head
 - Alternator
 - Double acting modifications to adapt from single cylinder to multi-cylinder operation
 - Integrated engine module
- Conduct manufacturing cost analysis
- Verify the impact of the reduced engine O&M costs on the LCOE of a CSP system
- A conservative value for a 30-kW heat drive cost resulted in a LCOE in the range of 7 to 15 ¢/kWh, depending on subsidies and financing alternatives.

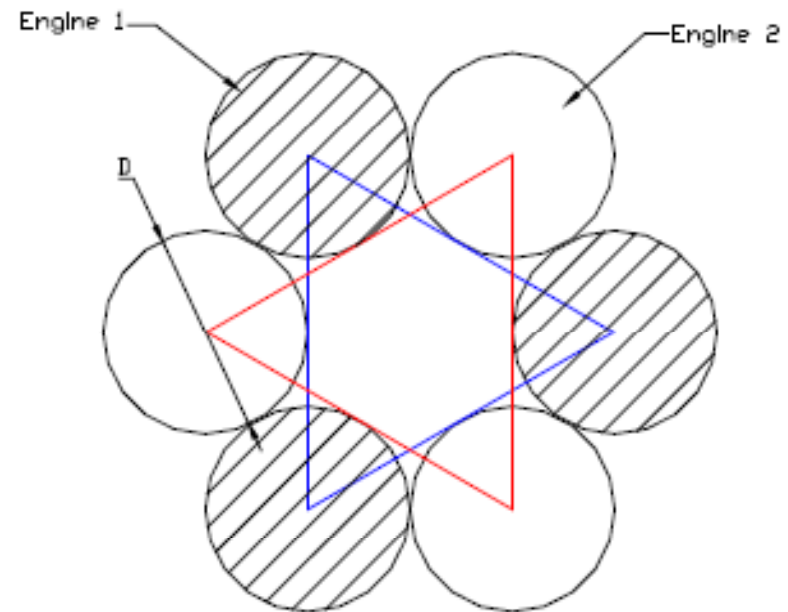
30kW Design

- 6 Interconnected 5kW engine cylinders configured into a pair of 15kW engines
- Relative piston phasing cancels out vibration
- Estimated weight for the prototype, 900kg
- Preliminary production weight estimate of about 540kg



30kW Design

- Engine 1 and 2 are connected as shown
- Simplest configuration to interconnect that produces no net vibration



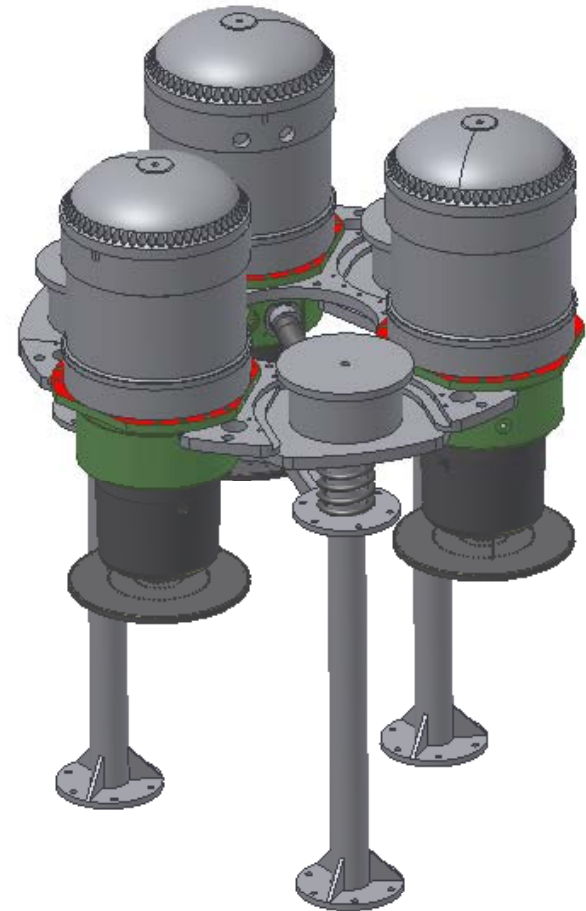
5kW ENGINE MODULE

- Estimated weight of prototype modules: <130kg
- Preliminary estimate for a production engine module is about 80kg



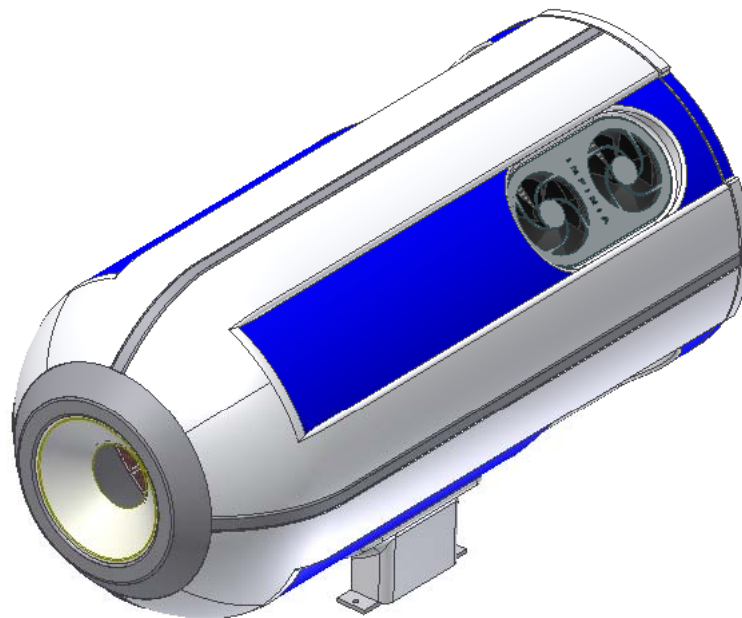
30kW Testing

- 15kW engine modules will be separately tested
- Induction heating used for heat input
- Enables tuning a single engine
- Spring mounts accommodate nutating motion of single engine module



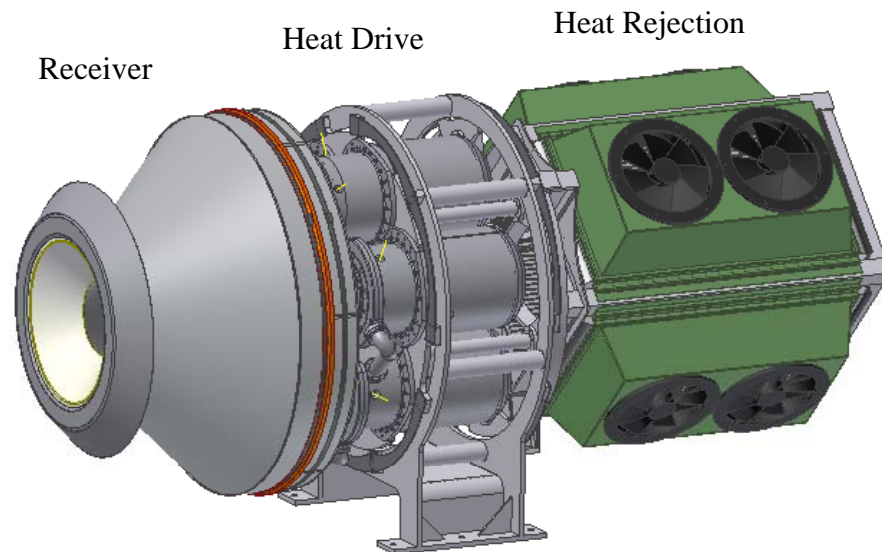
30kW Heat Drive Conceptual Design

- Boom mount 30kW Engine & required Balance of Plant



30kW Heat Drive Conceptual Design

- Heat drive major components
 - Receiver
 - Engine Assembly
 - Heat Rejection System



I N F I N I A

Thank you

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