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FISC RPS Community Presentation

DRPS Program

Contract Number: 80GRC017C0007

May 8, 2018

smarter, cleaner
... better energy

Agenda

May 8, 2018

- Technology Overview
- FISC Overview
- System Design
- Robustness and Risk
- FISC Performance
- Verification Plan

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Bottom Line Up Front

- Ongoing TDC demonstration at over 100,000 hours operation with no signs of degradation
  - 4 units have been on test since early 2000's
- The Flexure-based Isotope Stirling Convertor (FISC) is and evolution of the long life TDC design
- FISC design will meet requirements
  - Proposed changes were rigorously evaluated to minimize mission risk
  - Maintained TDC heritage/similarity when possible
- FISC design is based on 15+ years of product deployment experience from AMSC/Qnergy
  - Will meet or improve on contract reliability and provide robustness goals of contract
- System concepts include features that enhance reliability and efficiency

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Technology Overview

TDC History

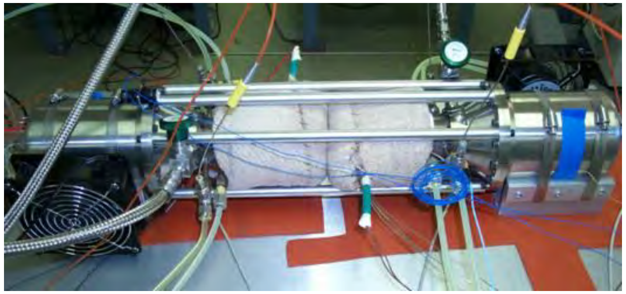
A Firm Foundation for FISC

The People and Knowledge

- Stirling Technology Company (STC) was founded in 1985, with 19 years of prior FPSE experience
  - STC was renamed Infinia (2005), ITC spun off from Infinia (2011), both groups acquired by Qnergy (2013); AMSC acquired the ITC spinoff group from Qnergy in 2017. Qnergy is partnering with AMSC.
- All key personnel from TDC / SRG projects are still on or accessible to the AMSC team
  - Original STC founders are still present with the AMSC to lead the FISC design team
- Teledyne system integration experience will play a key role in guiding FISC interface design

The Product Heritage

- The first pair of TDC units were designed, fabricated and tested in 1998-1999 under a GRC SBIR
- "Prototype" TDC / SRG design was "Frozen" around 1999/2000 and program was stopped in 2006
- AMSC/Qnergy team have continued working technology advancements since 2006



Balanced Pair of TDC Units

Substantial technology and infrastructure from AMSC, Qnergy and Teledyne are available to support FISC development

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FISC Heritage

Combines basic TDC technology with a well developed production system

- TDC design was the basis for FISC
  - >100,000 hour test data legacy from each of four TDC units
  - No observable degradation
  - Disassembly evaluation of one convertor confirms no identifiable failure mode progress
    - Provides reference case for RILT evaluation
- FISC retains key design and assembly elements critical to reliability and performance
  - Flexure bearings with clearance seals
  - Original TDC displacer design
- Convertor production system (from commercial line) provides a mature product quality control system
  - Assembly processes for production convertor will be mapped to FISC production

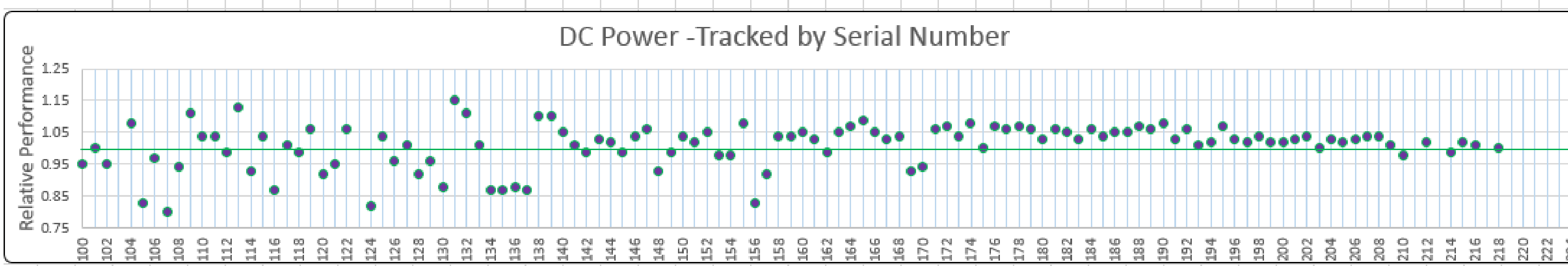
FISC will build on TDC legacy while maintaining core technology, components and architecture

Qnergy Production System

QB80, 6 kW convertor production pathfinder

- Qnergy B80 Intertek-Certified Convertor Package
- Key aspects of producing reliable product
  - Continuous Improvement
  - Create Standards and Procedures
  - Carry Margins

2017/12/05 **QB80 - Performance Status** 7045-102032-000



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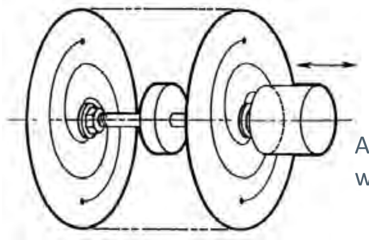
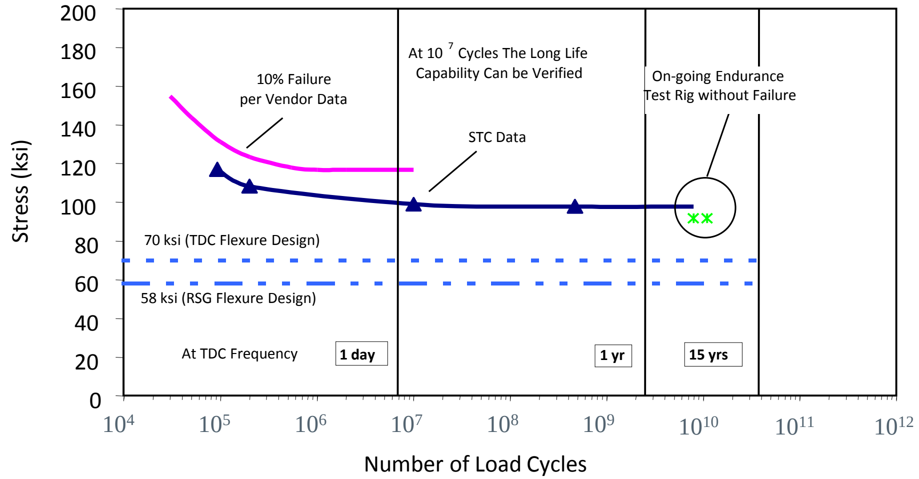
Technology Overview

Flexure Bearings

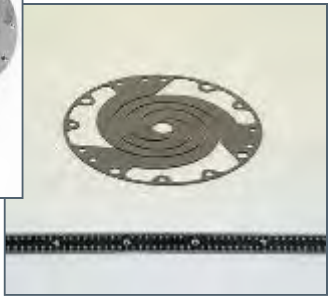
Flexure Bearings with Clearance Seal Technology is Unique Differentiator for Long Life, No Maintenance



Precise Linear Motion Enables The Use of Close Clearance Non-Contacting Pistons



Flexure Technology Since the 1960's



10-W Radioisotope Stirling Generator (RSG) Program

- >100,000 Hours on single laboratory RSG test
- Four fueled units demonstrated 5-year design life >5-uear, 43,000 hour design life

55-W Stirling Radioisotope Generator (SRG) Space Program

- Four units at NASA GRC exceeded 100,000 hours each
- Over 20 units fabricated
- Passed launch load and other qualification tests

All testing above with no maintenance and no performance degradation

High cycle fatigue in flexures well understood

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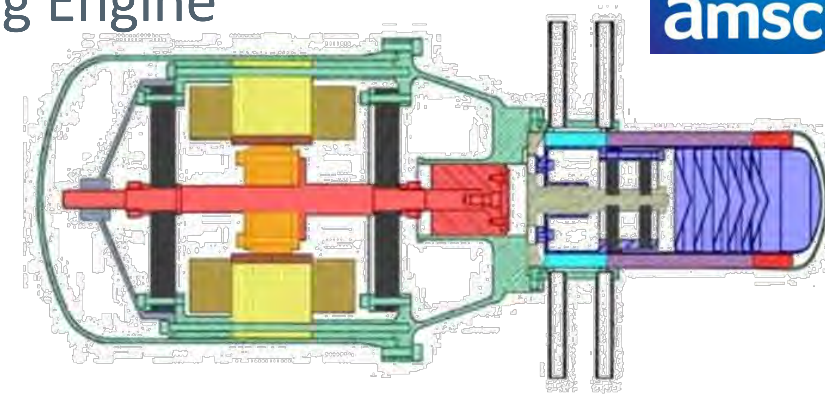
Technology Overview

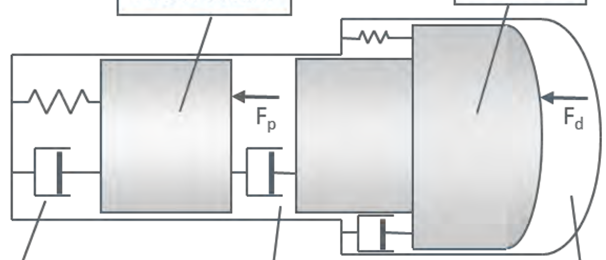
Flexure-Supported Gamma Stirling Engine

Analogous to the Electronic Bi-stable Oscillator

- Masses, damping coefficients, and springs can be modeled as inductance, capacitance, and resistance
- The two stable states are:
  - Non-oscillatory
  - Oscillation at the resonant frequency



Cross Section of 55We TDC Free-Piston Stirling



Mechanical Schematic of Free-Piston Stirling

- The spring system is comprised of mechanical springs, gas springs, and in the case of the power piston, a magnetic spring
- The linear alternator is the damping against which the engine operates
- Drive power to resonate the engine is supplied by the temperature differential across the engine
- The working fluid acts like an anti-spring (negative spring constant) acting against the displacer

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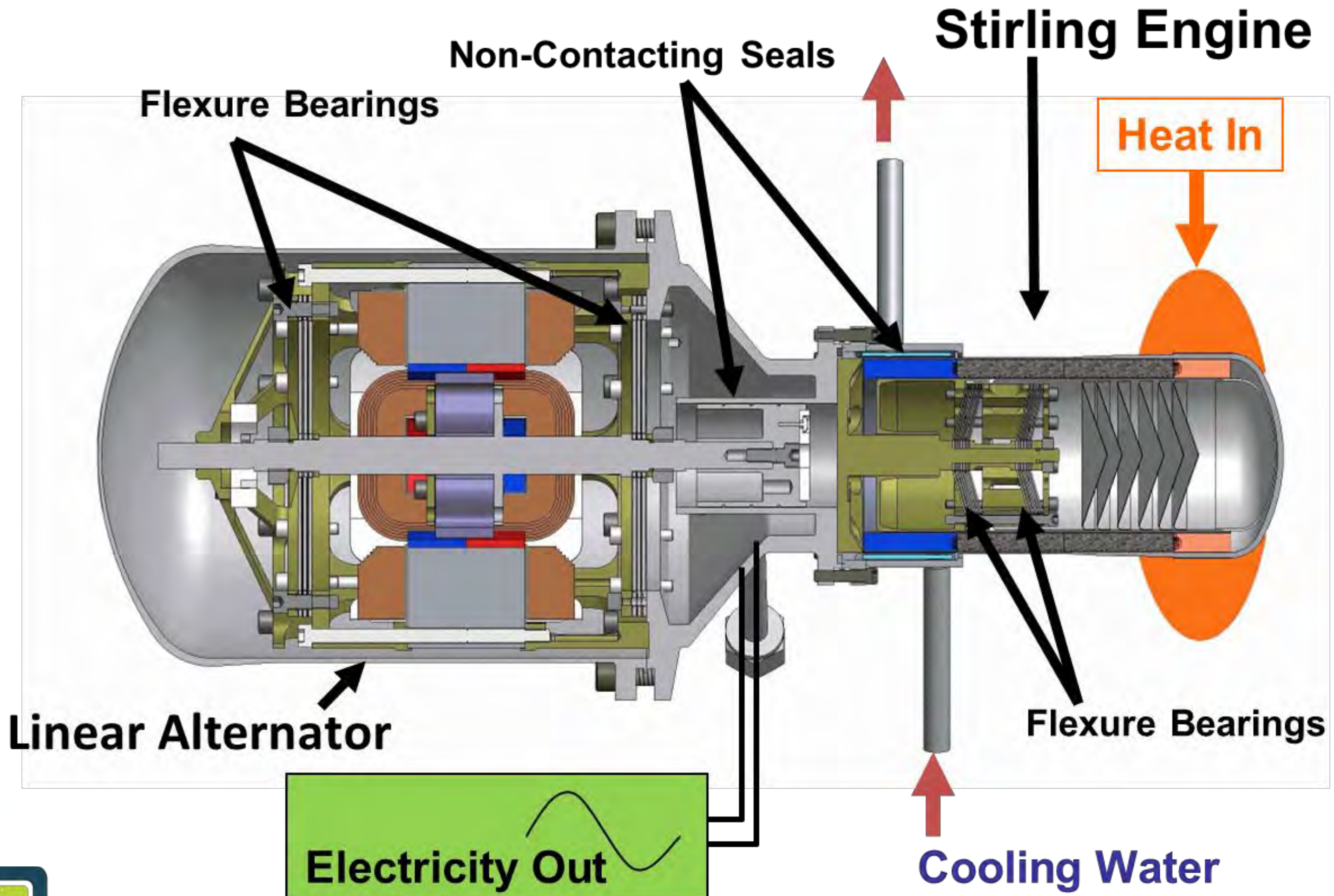
Technology Overview

Major Components



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FISC Overview

FISC Team

- AMSC
  - Core experience from TDC and numerous other free-piston Stirling projects
  - AMSC acquisition greatly expands product development background, capability & resources
  - Recent successful Stirling engine development program (ARPA-E GENSETS)
- Teledyne
  - RPS flight hardware and flight program experience
  - RPS Technology Maturation experience
  - System design experience
- Qnergy
  - Core experience from TDC and numerous other free-piston Stirling projects
  - Multiple Convertor product offerings range from 1-6 kW in the years since TDC
  - Manufacturing Commercial products – Reliable convertors
    - Presently Deploying Stirling-Based Remote Generator and mCHP Systems

Exceptional team capabilities to meet FISC and follow-on NASA DRPS needs

Top-Level FISC/TDC Comparison

Key Discriminators to Meet Mission Requirements

Mission Parameter	Units	Contract	FISC
Demonstrated Reliability at 20yr Continuous	[]	*>0.9[a]*	TBD – Phase 2
Convertor Specific Power (Testbed Config.)	[W/kg]	>20	21.7
Random Launch Vibe Tolerance – Hard Mount	[G-rms]	10.35	10.35
Maximum Cold-Side Operating Temperature	[C]	175	200
Static Acceleration Tolerance	[G-pk]	20	20[b]
Individual Convertor Power @100C Cold End	[W]	-	~70
Convertor Thermal to Electric Efficiency @100C	[%]	>=24	>24
Half-Heat Thermal to Electric Efficiency @100C	[%]	>=20	>20

(a) Reliability requirement is not explicitly called out in solicitation
(b) Displacer rub at > 12 g, but large Xylan rub tolerance

FISC will meet all contract requirements
and is very robust as discussed in following.
It is basis of the proposed design

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FISC Design Overview

General Description

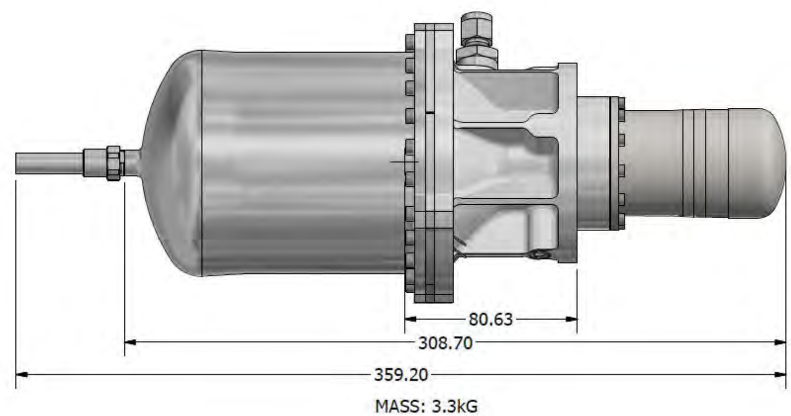
- Retains TDC Legacy/Architecture/Components/Form Factor
  - Basic Size/Shape, Similar Components
- Manufacturing features improve fabrication
  - Modular
  - Based on 15+ years subsequent experience and ~1000 units of product fabrication experience
- New Alternator to meet power density, high rejection temperature, and efficiency requirements
  - Moving magnet retained most TDC features and form factor
  - Materials selected to meet temperature requirements

Design changes limited to meet contract requirements and goals.

FISC Characteristics

Nominal full power operating point

665°C Absorber Temperature 100°C Rejection 250W Qin	
Operating frequency	81Hz
Output power	70W
Output voltage (RMS)	60V
Output current (RMS)	1.18A
Coil Inductance	54mH
Converter without hot shoe (integrated cold side adapter flange)	3.3kg 21W/kg



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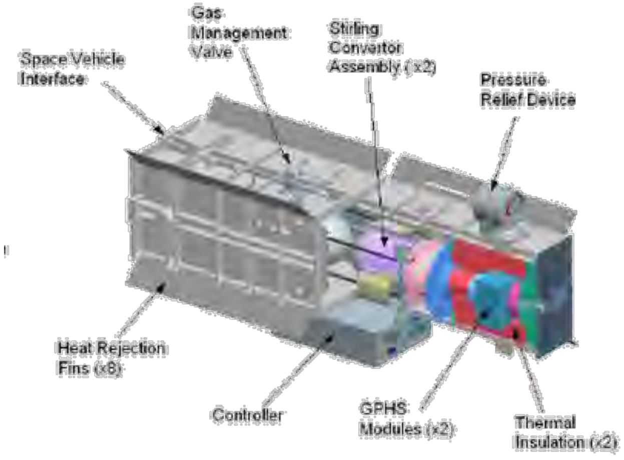
System Concept

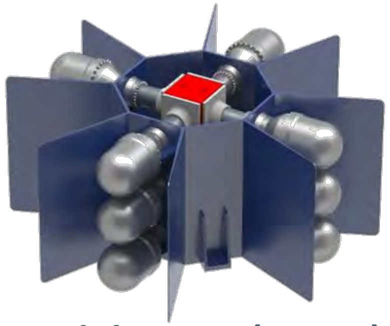
System Concept

Two basic options considered

- SRG configuration is baseline that is more fully developed but has limited growth capability and reliability issues
  - Multiple SRG's could be used to meet higher power levels
- MSRG is modular and can meet higher power level needs and can offer much more convertor redundancy
- Both work best retaining FISC power levels
  - No design driver to go to lower or higher convertor power levels
- This study is focused on the MSRG



Stirling Radioisotope Generator (SRG)

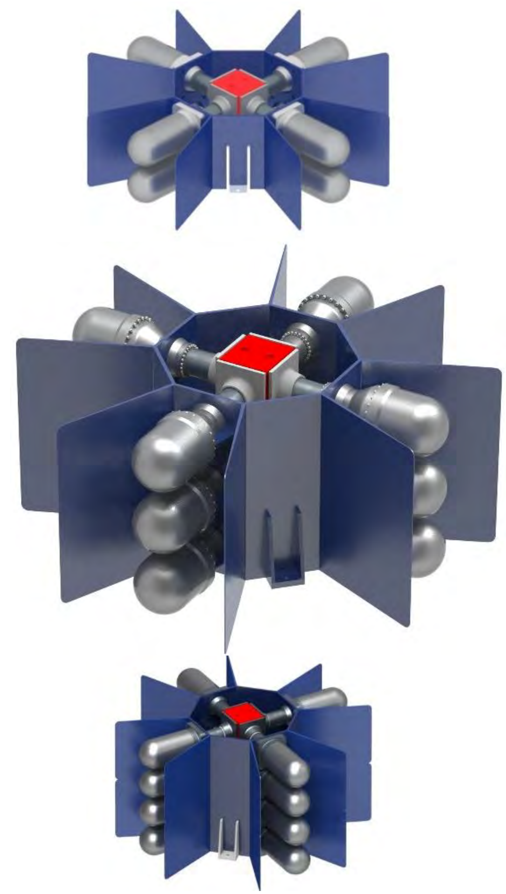


Modular SRG (MSRG)

System Concept

MSRG Overview

- Started with all options
  - SRG was also included due to heritage
- Evaluated system configuration options and impact on convertor power requirements
  - System study concluded that a power level of ~70W would be appropriate
- Focused on the Modular SRG (MSRG)
  - This made the most sense for meeting power level requirements as a single system
  - Also had some reliability advantages
  - System utilizes matched and balanced pairs of convertors.
  - Each layer has 4 convertors operating at ~50%
    - Allows for matched pairs to be shut down for redundancy
- Disclaimer: much more study needed to determine a final system implementation



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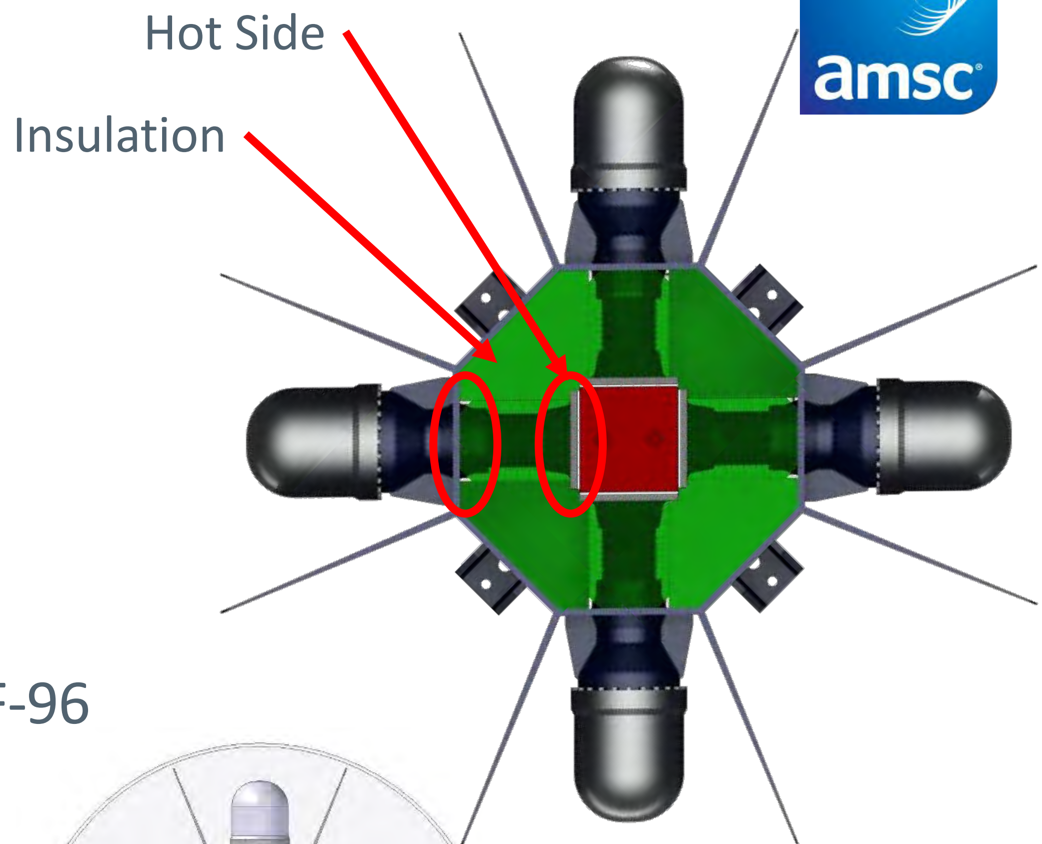
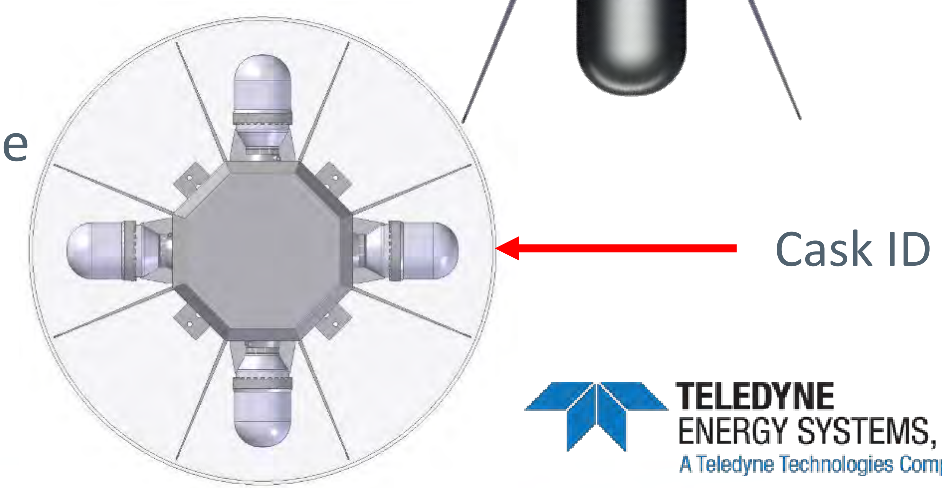
System Concept

- Interfaces
  - Hot side thermal
  - Cold side thermal
  - Mechanical
- Performance model and predictions
- Shipping Cask 9904/B(U)F-96
  - Currently a tight fit
  - Design options can enable reduced OD





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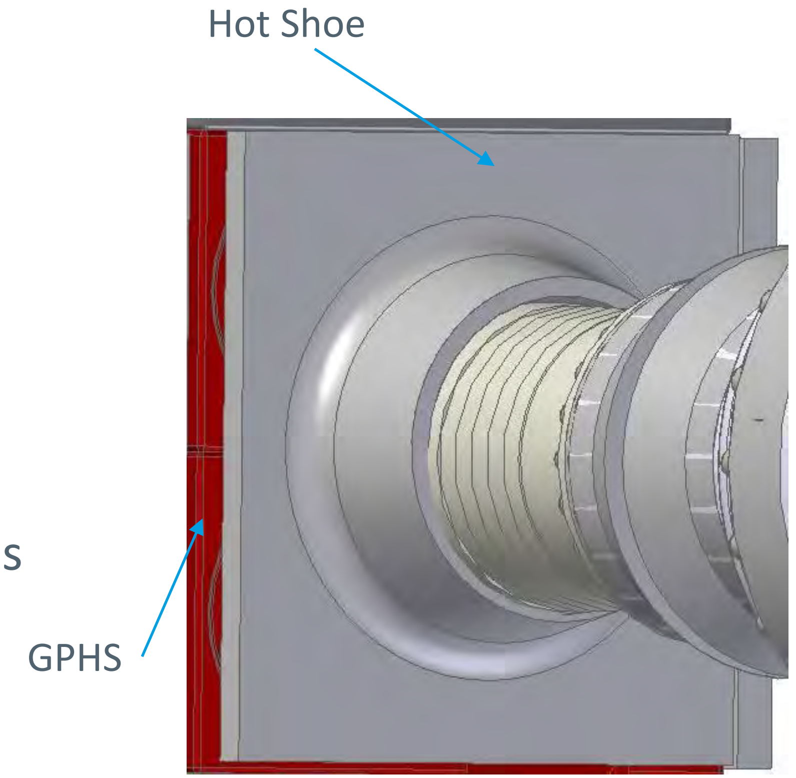
System Concept

Hot Side Thermal Interface

- Radiatively coupled hot side interface.
- Thermal radiation
  - Area ~97cm^2
  - Thermal power
    - All convertors operational: 125W yields 1.20W/cm^2 with 93.5% thermal eff.
    - 50% convertors operational: 250W yields 2.37W/cm^2 with 92.3% thermal eff.



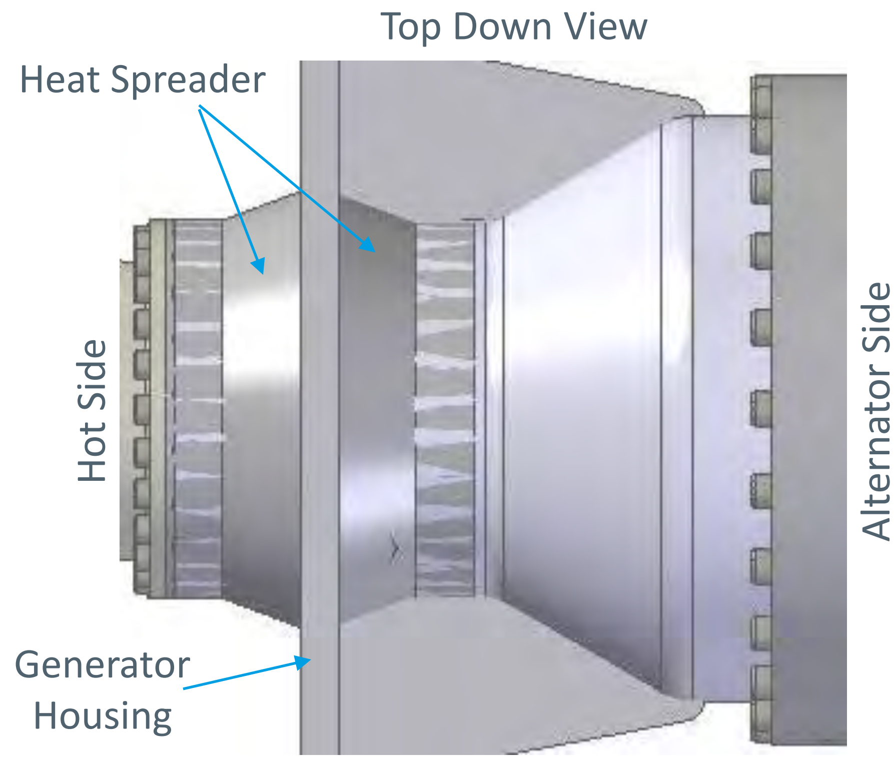
System Concept

Cold Side Thermal Interface

- The cold side thermal interface is integral with the mechanical interface. The central housing can be integrated with the generator housing.

- Conductive interface
  - Area ~71cm²
  - Thermal power
    - All convertors operational: 90.7W → 1.28W/cm²
    - 50% convertors operational: 166.8W →2.35W/cm²

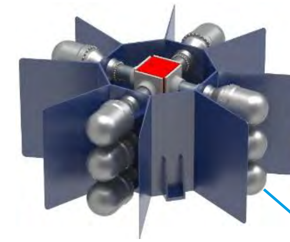
- Housing has fins to radiate to space or planetary environment

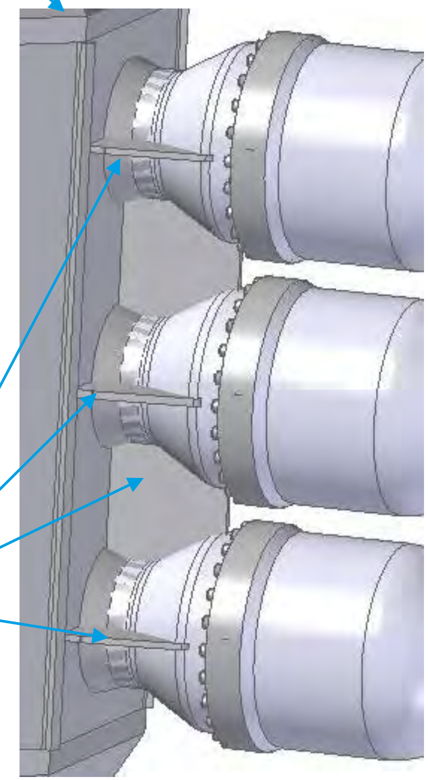


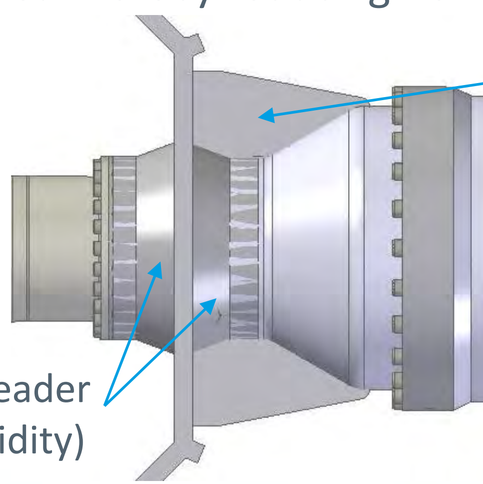
System Concept

Mechanical Interface

- The central coupling is integrated into the housing of the generator. Ribbing supports the bulk of the convertors.
  - The modular convertor design allows for independent QA checks on each sub-component prior to assembly reducing risk to the system assembly.
- Hot side interface is radiatively coupled → Mechanically disconnects the heated area thereby reducing hot side stresses.







Top Down View

Not most updated FISC design displayed. Newest FISC design does not effect generator approach.

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System Concept

System Model – Design & Assumptions

- Convertor specific weight 20W/kg – for weight calc. only
- Power Management is 95% efficient
- AC-DC conversion is 95% efficient
- All insulation is assumed to be MinK-1400 with Xenon cover gas
- Fin efficiency of 0.5 (very conservative)
- Assumes a body emissivity of 0.88 (MMRTG reference)
- Assumes cold side can be maintained at 100°C (by adjusting fin size)
- Housing, fins, and insulation weights are scaled from MMRTG equivalent components.
- Convertor efficiencies are listed here (650°C hot side – 100°C cold side)
  - System modelling used conservative power and efficiency curves.

Displacement (mm)	Power Out (W)	Convertor Efficiency
6	67.4	28.6%
5	48.9	26.6%
4	32.8	23.9%
3	19.2	20.2%

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System Concept

System Model – Results

Cover Gas		Xenon						Vacuum		
Convertors / Layer		4			2			4		
Redundant Convertors/ Layer		2			0			2		
Layers		2	3	4	2	3	4	2	3	4
GPHS		4	6	8	4	6	8	4	6	8
Power Out	W	188.9	282.8	377.6	239.7	360.7	481.4	198.2	299.1	398.9
System Efficiency	%	18.8	18.9	18.9	24.0	24.0	24.1	20.0	20.0	20.0
Convertor Efficiency	%	22.33	22.4	22.37	28.3	28.3	28.4	22.89	22.8	22.8
Thermal Efficiency	%	93.3	93.5	93.6	93.8	94.0	94.1	96.8	97.2	97.2
Weight	kg	61.0	88.5	116.0	44.2	63.3	82.4	61.0	88.5	116.0
Specific Power	W/kg	3.10	3.20	3.26	5.42	5.70	5.84	3.25	3.38	3.44

- Yellow columns have 0 redundant convertors – Leads to high power output and very high specific power.
  - 28% Less weight carried due to no redundancy
  - Convertors are 26% more efficient when operating near maximum power than half power.
- System + convertor design suggests the need for a 3 layer configuration to meet all requirements.
- Generator utilizes a cover gas (Xenon), but carries the option to vent to space if the mission desires it.
  - Better performance in space.
  - Potentially better performance in planetary missions.
  - Leak tolerant design.

MSRG 3-layer configuration gives plenty of margin for meeting system requirements while keeping fuel usage less than MMRTG

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System Concept

System Model – Results BOL vs EODL

		BOL	EODL	EODL
Time	Years	0	20	
Layers		3		
Convertors		12		
% Failed	%	0	0	50
GPHS		6		
Thermal In	W	1500	1281	
Power Out	W	282.8	220.1	280.4
System Efficiency	%	18.9	17.2	21.9
Convertor Efficiency	%	22.4	20.6	26.7
Thermal Efficiency	%	93.5	92.5	91
Weight	kg	88.5		
Specific Power	W/kg	3.20	2.49	3.17

System generates more power as convertors fail. Potentially generating more power as time progresses.

- Mission operators could choose to shutdown convertors to gain extra power as the fuel decays, at the expense of redundancy.

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System Controls

Parts Count Reliability Prediction (MIL-HDBK-217F)

$$\lambda_{Equip} = \sum_{i=1}^{n} N_i \left(\lambda_g \pi_Q\right)_i$$

λ_{Equip}	Total equipment failure rate (failures/10^6 hours)
N_i	Quantity of the i^{th} part
λ_g	Generic failure rate for the i^{th} part (failures/10^6 hours)
π_Q	Quality factor for the i^{th} part
n	Number of different generic part categories in the equipment

Assuming an exponential distribution reliability function for electronics:

$$R(t) = e^{-\lambda t}$$

$R(t)$	Reliability as a function of time, t

System Controls

Single Engine Controller Reliability for Highly Screened Parts

- Topology used in Lockheed Martin and JHU/APL Controllers
- H-bridge for active power factor correction (virtual tuning capacitor) and rectification
- Emergency shunt for load transients and shutdown
- Buck converter to match spacecraft bus and limit current rush

			QUALITY FACTOR	FAILURE RATE PER 10^6 HOURS
	N_i	$\lambda_{g,i}$	$\pi_{Q,i}$	λ_i
CAPACITOR, CERAMIC, GEN	200	0.00086	0.001	1.72E-04
CAPACITOR, ALUMINUM	10	0.00063	0.001	6.30E-06
CRYSTALS	5	0.016	1	8.00E-02
DIODE, SCHOTTKY	10	0.023	0.5	1.15E-01
DIODE, SWITCHING	20	0.00047	0.7	6.58E-03
FET, SILICON (f < 400 MHz)	20	0.0069	0.7	9.66E-02
INDUCTOR, FIXED	1	0.00002	1	2.00E-05
MICROCIRCUIT, LINEAR	15	0.033	0.25	1.24E-01
PCB	1	0.0025	1	2.50E-03
RESISTOR, FILM, CHIP	200	0.0018	0.03	1.08E-02
RESISTOR, WIREWOUND, POWER	1	0.0043	0.03	1.29E-04
		TOTAL		4.36E-01
		MTTF (HOURS)		2.30E+06
		MTTF (YEARS)		262.09
		R(20 YEARS)		92.7%

Estimated single convertor controller reliability for 20 years is 92.7%

Generator Level Reliability Analysis

Comparison of ASRG-like and MSRG configurations

- ASRG-like configuration
  - 0 of 2 convertors allowed to fail
  - 1 of 3 controllers allowed to fail

$$R_{sys} = {R_s}^2 \sum_{i=2}^{3} \binom{3}{i} {R_c}^i (1 - R_c)^{3-i}$$

- MSRG configuration
  - 3 of 6 pairs of convertors allowed to fail
  - 1 of 2 controllers / convertor allowed to fail
  - System controller modelled as same complexity/reliability as a convertor controller

$$R_{sys} = \left[\sum_{j=3}^{6} \binom{6}{j} \left({R_s}^2 \left(\sum_{i=1}^{2} \binom{2}{i} {R_c}^i (1 - R_c)^{2-i} \right)^2 \right)^j \left(1 - {R_s}^2 \left(\sum_{i=1}^{2} \binom{2}{i} {R_c}^i (1 - R_c)^{2-i} \right)^2 \right)^{6-j} \right] R_{sc}$$

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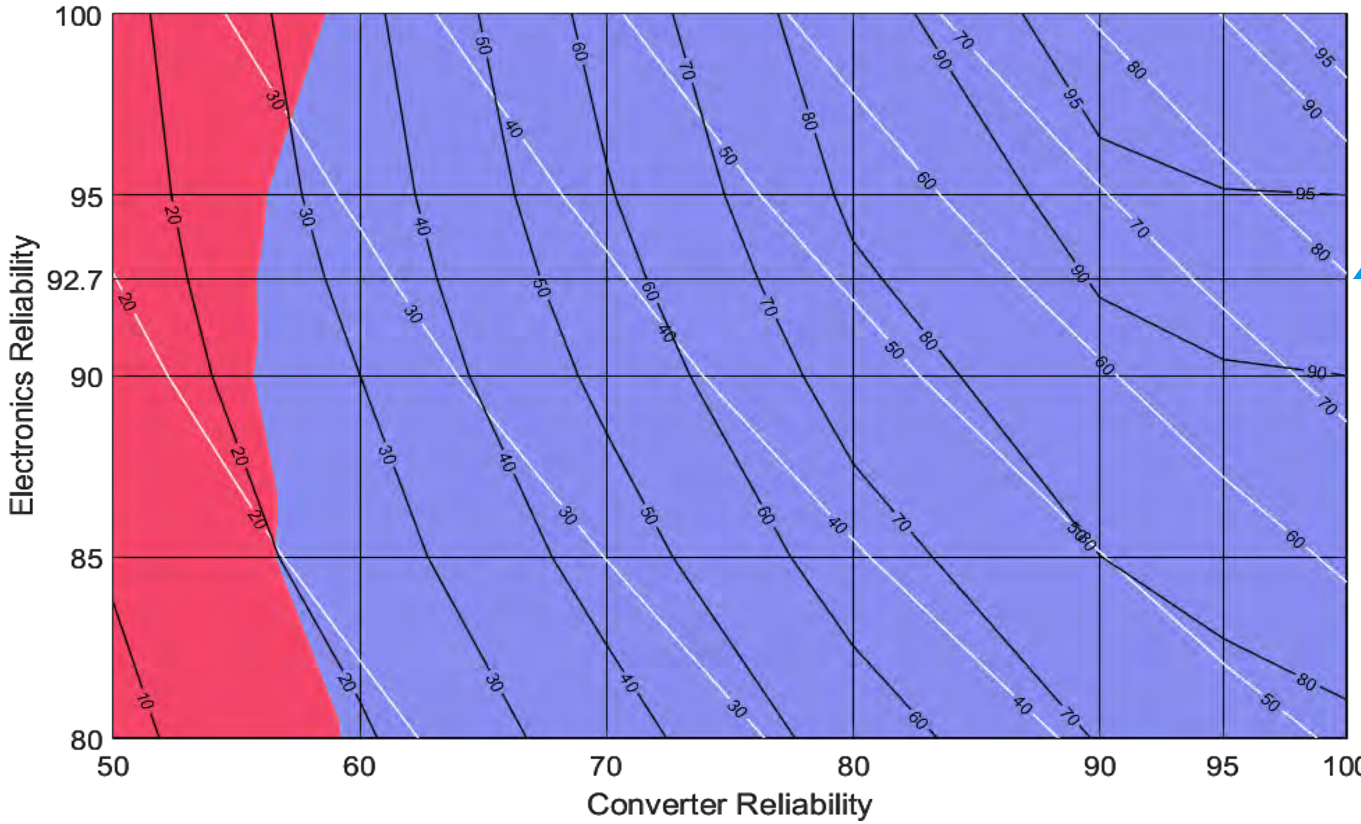
Generator Level Reliability Analysis

20 year reliability comparison of ASRG-like and MSRG configurations



Estimated Single Convertor Controller Reliability at 20yrs

- White curves – ASRG-like reliability contours
- Black curves – MSRG reliability contours
- Pink section – region where the ASRG-like configuration is more reliable than the Spoke configuration
- Purple section – region where the MSRG configuration is more reliable than the ASRG-like configuration

MSRG is more reliable than ASRG-like configurations in the design space of interest

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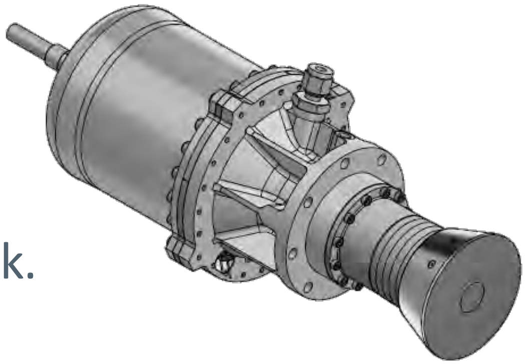
Requirements and Performance

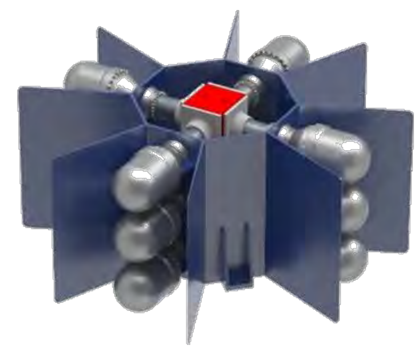
Description	Contract	MSRG	Approach
Generator Power Output	200-500We	282.8We	12x FISC convertors with 100% redundancy
Transmitted Forces	<10N	Theoretical 0-N	Synchronized pairs will be shutdown synchronously when a failure is detected.
System Level Efficiency	>20%	~20%	System allows for hot side cover gas to be vacuum, xenon, or other non-corrosive gases. (20% rating under vacuum)

System Design

Summary

- Key features
  - 100% Convertor redundancy
  - System generates more power if convertors fail.
  - Convertor pairs eliminate transmitted vibration
  - Simplifies fueling procedures by utilizing a central stack.
- Minimizes system risk (ongoing risk analysis)
  - Convertors utilize TDC heritage
  - System utilizes MMRTG heritage
  - Eliminates hot side convertor loading
  - System is multi-fault tolerant
- Design is still in early development
  - E.g. Analysis regarding off nominal (100°C) cold side temperatures needs to be performed.





MSRG provides one attractive implementation of the FISC

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Robustness and Risk

Robustness Assessment

Environmental Considerations

- FISC Currently Capable of 175°C+ continuous rejection temperature
  - Limited by alternator organic materials
- All FISC pressure boundary analysis has been done with the internal pressure as absolute pressure.
- Proposed pressure boundary 6061-T6 aluminum.
  - Deep Space
    - Operation in vacuum environment will not be an issue
  - Earth atmosphere operation compatible
  - Mars
    - Partial pressure high CO_2 atmosphere safe
  - Titan
    - External pressures of 1.5bar will not present a problem
    - Aluminum-methane interaction compatible
- Investigating performance and weight impacts of using legacy TDC materials for pressure boundary

Robustness Assessment

Convertor – Off Nominal Operating Conditions

Approach to Off Nominal Operating Conditions

- Axial Vibration and Static g-loading
  1. Large over-stroke headroom (>1mm)
  2. Bumpers to prevent damage
- Lateral Vibration and Static g-loading
  1. Alternator flexures springs are much stiffer in the lateral direction
  2. Xylan coating to protect from damage in case of rubbing
  3. No mechanical catches (all smooth surfaces)
- Loss of electrical load
  1. Bumper concept to protect piston in the event of over stroke under evaluation during Phase II

Vibration and static g-loading have 5 mechanisms which protect the convertor from damage during these events

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Robustness Assessment

Convertor – Off Nominal Operating Conditions (cont'd)

- Hot side over temp
  1. Hot side materials allow for excursion to 760°C (+110°C above nominal) – Creep is the only limiting factor
  2. Recommend extra headroom on generator design
     - Generator design at maximum expected usage is at ~95% of stroke allowing for some thermal deviations.
- Cold side over temp
  1. Cold side materials designed to at least 200°C, +25°C above nominal operating range (175°C)
  2. Alternator pressure boundary material is aluminum to increase heat transfer and reduce the chance of over-temperature concerns

Hot side and cold side over-temperature events have thermal margin and increased heat transfer margins.

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FMECA, Risk

Convertor Level

- FMECA
  - AMSC is working to reduce the highest criticalities related to the bumpers and position sensor.
  - Most medium criticalities are related to the new alternator.
- Risk
  - Primary risks are due to the new alternator design
    - Newness of alternator
    - High temperature organic bobbin materials
    - High temperature magnets
    - High temperature adhesives
    - Radiation degradation of organics
  - High priority risks have clear mitigation path

FISC is a robust solution with manageable risks

FISC Performance

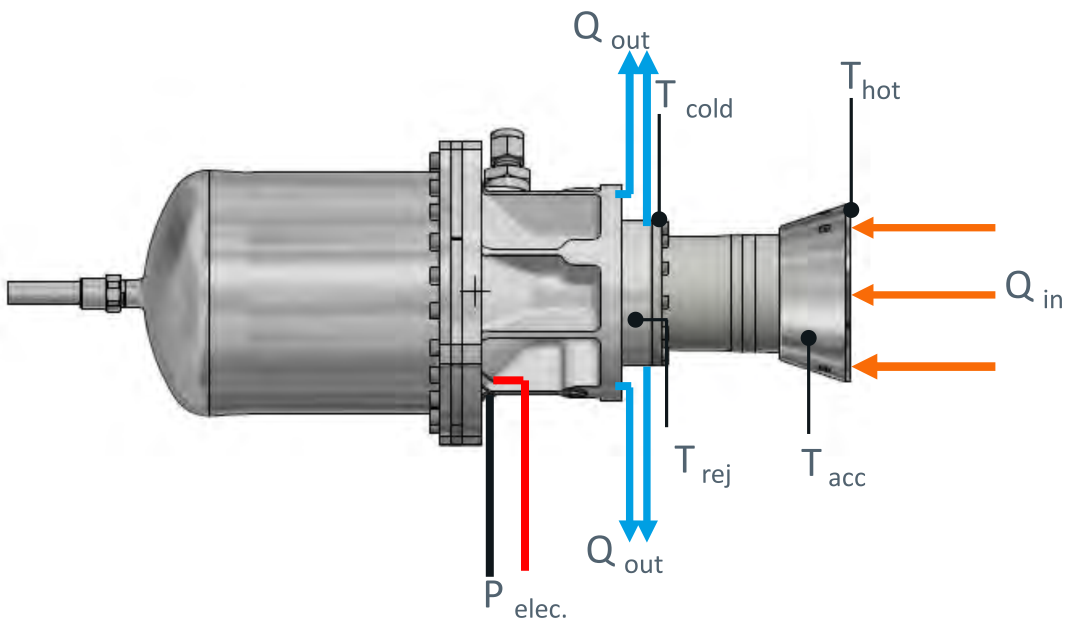
FISC

Thermal Interfaces

- The accepter thermal interface for FISC is a nickel hot shoe absorber
- Rejection occurs in the location marked Q_{out}.
- The rejector interface is a conductive interface that can mate directly to radiation panels, or be used with a pumped coolant loop
- Thermal resistance for the hot shoe to the fins shown is ~0.26°C/W, $\Delta T_{acc} \cong 65°C$ for $T_{hot} \cong 665°C$ $T_{acc} \cong 600°C$
- Thermal resistance helium passage to the flat rejection flange ~0.038 °C/W, $\Delta T_{rej} \cong 5°C$ for $T_{cold} = 100°C$ $\Delta T_{rej} \cong 105°C$
- Carnot Efficiencies reported based off of T_{hot} , T_{cold}.

$$\Delta T_{rej} = T_{rej} - T_{cold}$$

$$\Delta T_{acc} = T_{hot} - T_{acc}$$



T_{acc} =accepter innermost channel temp

T_{rej} =rejecter innermost channel temp

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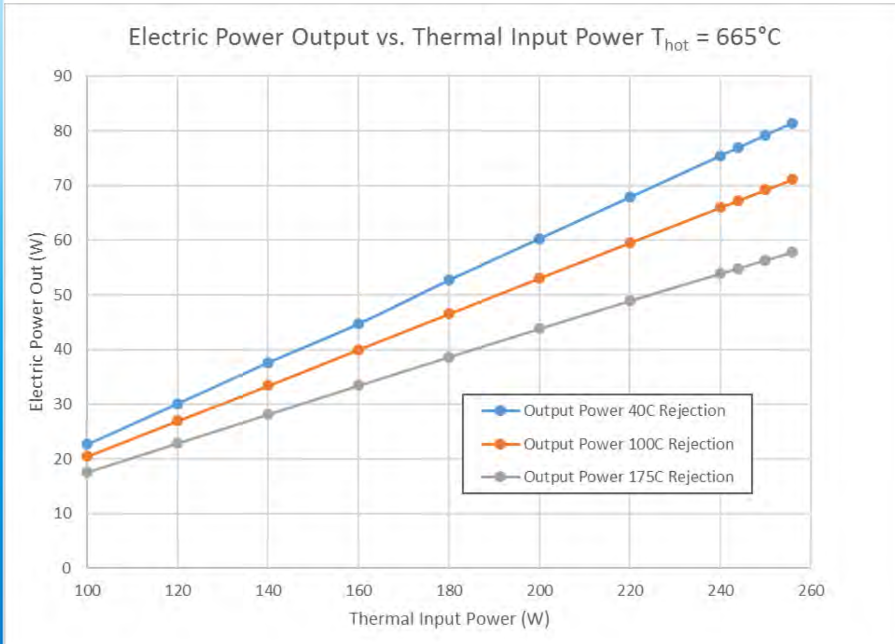
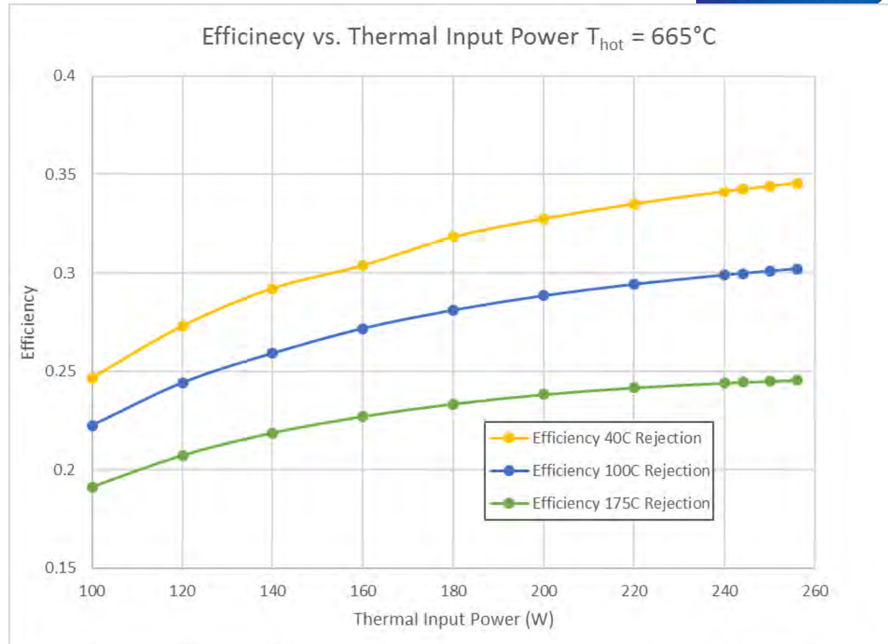
FISC Performance

Power and Efficiency





Efficiency: 20%-30%

~50% of Carnot at operating conditions

Values in table: T_{cold}=100C	250 W Qin	120 W Qin
T_{hot}	~665C	~665C
Piston Amplitude	6mm	3.4mm
Electric Power Output	~70W	~24.4W
Efficiency	~30%	~24.4%
%Carnot	~50	~41

RMS Voltage Output: 30V-63V

RMS Current Output: 0.7A-1.2A

Verification Plan

FISC Development Stages - Proposed

Basic Validation Testing RoadMap

Hardware Quantity	0	2
Design Evaluation Method	Stage 1	Stage 2
Analytical Risk Assessment	x	x
Quality Inspection		100%
Basic Performance Investigation / Mapping		x
Sensitivity to Enforced Variation		
Flexure Durability Testing		
Accelerated Life Testing		
Flight Qualification Testing		
Design is "In Control"	>80%	>90%
NASA Program Phase	1	2

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Verification Plan

Summary

- A complete verification approach has been drafted during Phase 1 and submitted to NASA covering all requirements
- Phase 2 will focus on
  - Updating FMECA and evaluate design related risk reduction
  - Performance verification

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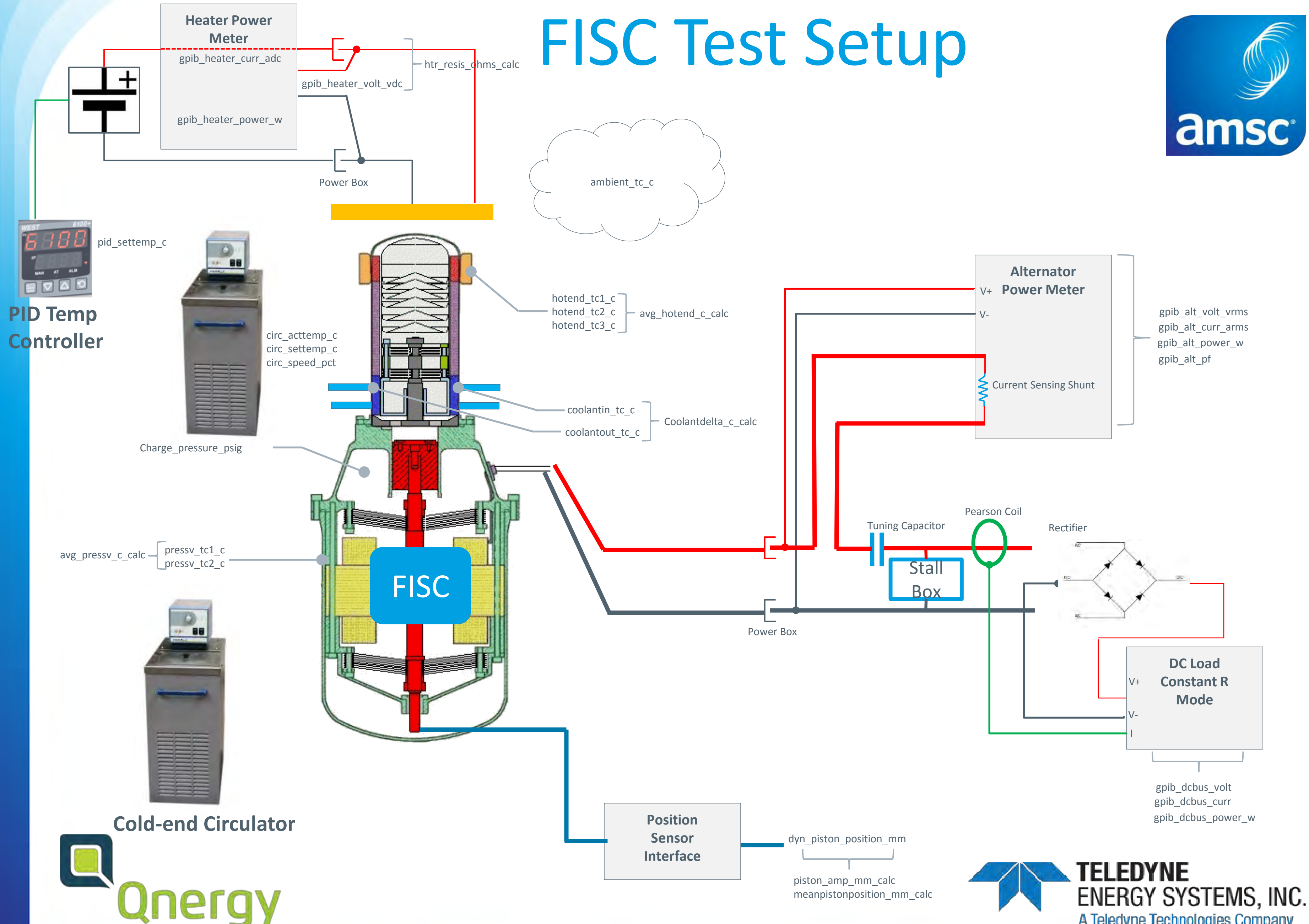
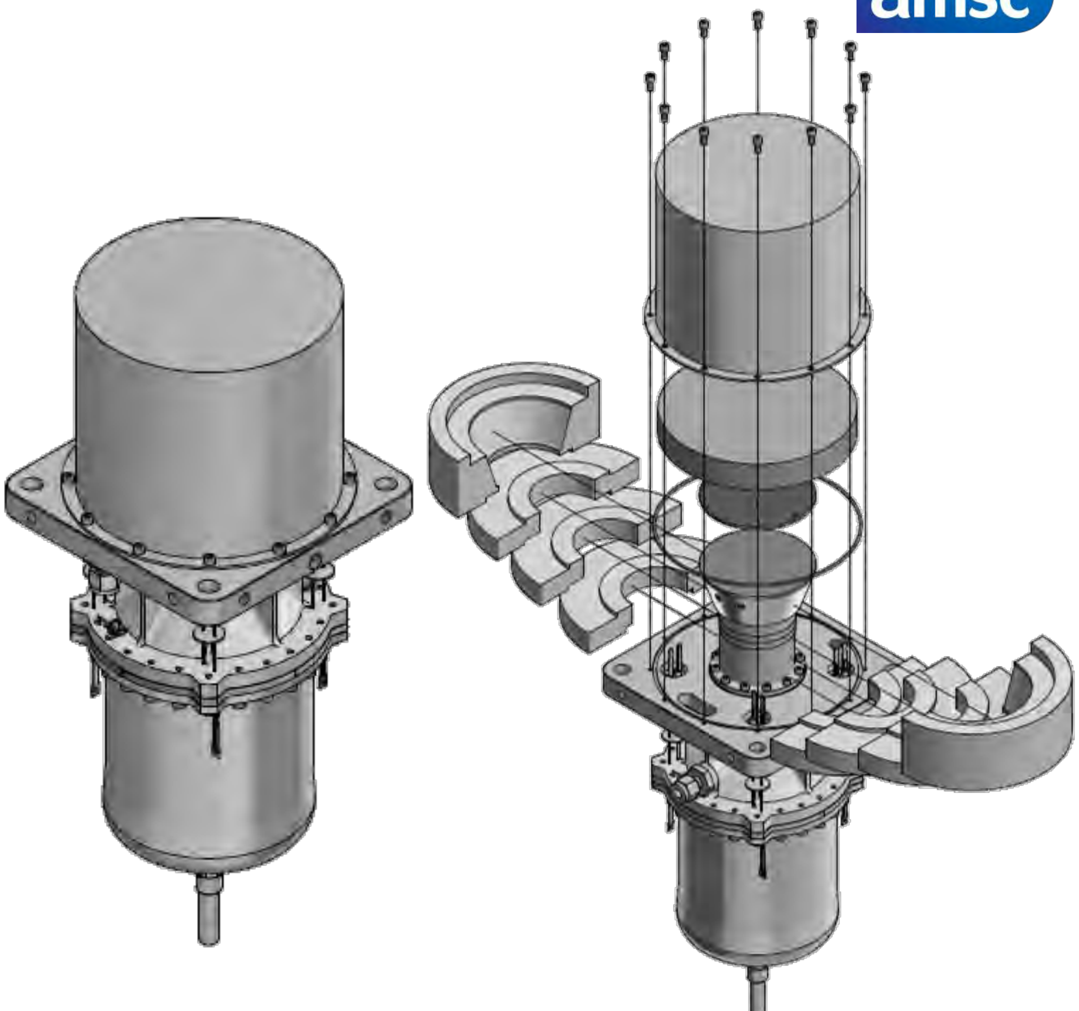
FISC Test Setup



FISC Assembly

Test Assembly

- Heat source for testing will be a pyrolytic graphite, pyrolytic boron nitride electric heater
- MinK-1400, or similar insulation will be clam shelled around the heater head
- A stainless steel pressure vessel will install onto the stainless test mount plate
- The test plate has several mounting hole patterns so that converter can be mounted in different orientations
- Single converter testing will be conducted with the converter attached to a large vibration isolated mass to keep the case amplitude low; ~0.051mm
- Must be analyzed for vibe and accel tests.



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Test Bed Convertors vs Deliverables

Fixed Power Electrical Heat Source to Drive Test

Test Bed Convertors Will Carry Additional Instrumentation

Test Beds Will Be Used During Hardware Optimization/Sensitivity Investigations

Control Method – Bridge Rectifier and a **Variable-Resistance DC Load**. Feedback Control to Manage Fixed-Amplitude

Measurable	Test Bed
Voltage/Current/Power	☑
Piston Position	☑
Mean Charge Pressure – Bounce Space	☑
Heat Source Power (and Insulation Heat Loss)	☑
Joulimetry at Cold Plate Mounting Block	☑
Joulimetry at Pressure Vessel Heat Sink	☑
Hot Shoe Temperature in 4 Places	☑
Cold Coupler Temperature in 2 Places	☑
Rear Pressure Vessel Temperature in 2 Places	☑
Heat Source (Radiation) Temperature, 2 Places	☑
Hot End Dome Temperature – Top Dead Center	☑
Additional / Optional Internal/External Surface temperatures	☑
Displacer Position	☑
Compression and Bounce Space Gas Temperatures	☑
Compression and Bounce Space Dynamic Pressures	☑
Acceleration on the Generator Simulator Test Frame (3 Axes)	☑
Other – TBD	☑

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Types of Verification Testing

Fabrication and Inspection	Component Salient Characters	Subassembly Key Process Characters	Convertor Assembly – Nominal Tests
Dimensions	Masses and Stiffness	Torque/Turn and Preload	Evacuated Heat Loss testing
Surface Finish	Resistance, Inductance	DC Gas Flow Loss	Optional Internal Volume Verify
Visual Quality	Magnetic Quality	Seal Leakage Rate – As Built	Optional Auto-Refrigeration Rate
Cleanliness	Absorptivity and Emissivity	Electromagnetic Performance	250±6W xxx/100/-15C Acceptance Test
Mechanical Properties	Gas Purity (Pre-Pure or Better)	Dynamic Frequency and Damping	250±6W Cold End Mapping
	Off-Gas Time	Flexure Stack Reliability	Heat Source Mapping (Redundancy)
			250±6W – >2 Year Endurance test

Verification Matrix Gives More Details

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Verification Plan

Summary

- FISC is a “New” prototype
  - Based on TDC legacy, but carrying newness that must be retired
  - The FISC team will assess and retire risks
- FISC is planned to mature in phases and stages
  - Based on maturity and appropriate validation
- FISC will mature quickly
  - Based on TDC.
  - Based on 15+ years of learning since TDC
- BUT – NEWNESS Risks must still be retired
- GOAL of FISC Team is to “PROVE IT”
  - By analysis margin and by test
  - To use any tests to assist the RILT effort
  - To use validation testing to correlate models
- To make Probability of Success predictable with confidence

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Thank You