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Subject: FCF Service Life Extension

The Fluids and Combustion Facility (FCF) project intends to extend the operational/service lifetime of Combustion Integrated Rack (CIR) and Fluid Integrated Rack (FIR) through 2028 in accordance with guidelines of SSP 50699-04. Both the CIR and FIR racks are identified classified as facility class payloads. This assessment follows the approach outlined in SSP 50699-04 paragraph 3.1.3.5.

Neither the CIR nor FIR racks are certified for safe design life to 2028. The current safe design life and safe operational life of these racks are defined on Certificate of NSTS/ISS Payload Safety Compliance, JSC From 1114A in their respective Safety Data Packages as follows:

CIR	Years	Start	Expiration	Reference
Safe design Life	15	10/29/2008	10/29/2023	CIR-DOC-3850A
Safe operational Life	1	6/11/2012	6/11/2013	CIR-SDP-4265

FIR	Years	Start	Expiration	Reference
Safe design Life	15	Nov 2008	11/2023	FIR-DOC-1712A
Safe operational Life	15	Nov 2008	11/2023	FIR-DOC-1712A

1 CIR

The various components and sub-systems of the CIR are discussed below to show that acceptable risks for life extension through 2028 can be achieved and that effective means exist for monitoring safety controls and inhibits for failures. This provides the rationale to classify these subsystems as run-to-failure.

1.1 CIR Pressure System Soft Seals Life Concerns:

The soft seal materials used in the CIR racks are overwhelmingly Fluoroelastomer and PTFE with Polyimide, PEEK and PCTFE also used in the FOMA. These seals are all used in static or low duty cycle make/break configurations, over a benign temperature range and in a clean, non-corrosive environment. Reference CIR-LST-0051 Rev A, Material Identification/Usage List.

While these materials are generally not considered to have a life limit when in a controlled environment such as the ISS, each of the applications has been reviewed to determine if they are safe to run to failure.

The CIR contains 5 pressurizes sub-systems. The general discussion above is applicable to each of these sub-systems, The 5 CIR pressurized sub-systems are indented as follows:

FOMA	Fluid/Oxidize Management Apparatus
Gaseous N2	GN2
ITCS	Intermediate Temperature Control System
VES	Vacuum Exhaust System
VRS	Vacuum Resource System

FOMA

The FOMA system contains the following soft seal materials: Fluoroelastomer (code 05005), PTFE (code 00016), Polyimide (code 05123), Polyimide with Graphite (code 05122), PEEK (code 80546), and PCTFE (code 05521). A discussion of these seals and their usage is provided in paragraph 1.4, Non-ORU Limited Life Concerns.

ITCS

As documented in the EXPRESS Safety Life Certification white paper, 5-5165-DC-10-0121, the ISS leak detection algorithms are capable of detecting minute leaks, even before they become observable to the crew. Some, but not all internal ITCS components are ORUs and are spared. Individual failures would need to be evaluated to determine if the rack can be repaired and brought back on line.

<u>Quick Disconnects – Preece 51410 series</u>

The QDs have either PTFE (code 00016) or Fluoroelastomer (code 05005) static seals that have been leak tested after assembly. The QDs have redundant Fluoroelastomer (code 05005) dynamic seals. These seals are only dynamic when mating or demating the QDs. The QD cap contains the secondary seal for the QD in the un-coupled state. If both seals were to leak the CIR rack would need to be isolated from the ITCS system by demating the rack fluid umbilical's.

GFE Quick Disconnects – Parker Stratoflex
These QDs are supplied by the ISS program and are not evaluated in this document.

Flow Sensor – Preece N1059-777
The Flow Sensor contains four PTFE (code 00016) static seals that are leak tested after assembly.

Water Metering Valve – Preece N1059-555
The Metering Valve has PTFE (code 00016) and Fluoroelastomer (code 05005) static seals that are leak tested after assembly. The Metering Valve has PTFE (code 00016) and Fluoroelastomer (code 05005) dynamic seals. These seals are only dynamic when making adjustments to the internal rack flow rates. This activity is only performed when a significant power level change has occurred. This has only occurred once for the CIR rack. If the two PTFE seals were to leak it would be a minor consequence of internal leakage when the flow valve is in the fully closed position. The fully closed condition has never been used on the CIR rack. If the one Fluoroelastomer seal was to leak it would allow leakage to the cabin. In this situation the CIR rack would need to be isolated from the ITCS system by demating the rack fluid umbilical's.

Flexible Hoses – Titeflex
The Flexible Hoses are a PTFE (code 00016) core with a Nomex outer braid and stainless steel fittings. The Flexible Hoses do not contain any soft seals.

Hard Lines & Fittings
The hard Lines & Fittings have either PTFE (code 00016) or Fluoroelastomer (code 05005) static seals that have been leak tested after assembly. The EPCU contains a cold plate interfacing with the ITCS. The EPCU is an ORU and is spared.

Heat exchangers
The ATCU heat exchanger in the CIR rack does not contain any soft seals.

Accumulator
The CIR rack was launched with accumulator that has been disconnected when the rack umbilical's were mated, but is still mounted to the rack. The accumulator body (Belfab 63980A001) and QD (Parker Stratoflex) were GFE items and have not been evaluated in this document. CIR provided the flex hose which is the same construction as the flex hoses detailed above. The Accumulator has PTFE (code 00016) and Fluoroelastomer (code 05005) static seals that have been leak tested after assembly.

Gaseous Nitrogen System (GN2)

As the ISS program closely monitors the use of nitrogen, it is assumed that the ISS leak detection algorithms are capable of detecting minute leaks.

Flexible Hoses – Aeroquip
The Flexible Hoses are a PTFE (code 00016) core with a stainless steel outer braid and stainless steel fittings. The Flexible Hoses do not contain any soft seals.

Quick Disconnect – Preece 942 series
The QD has a Fluoroelastomer (code 05005) dynamic seal. This seal is only dynamic when mating or demating the QD. This QD interface is not cycled under nominal crew operations. If the seal were to leak, GN2 would be released to the cabin and the CIR rack would need to be isolated from the ISS nitrogen system by demating the rack umbilical.

Quick Disconnect – Preece 51410 series
The QD has redundant Fluoroelastomer (code 05005) dynamic seals. These seals are only dynamic when mating or demating the QD. The QD cap contains the secondary seal for the QD in the un-coupled state. If both seals were to leak, GN2 would be released to the cabin and the CIR rack would need to be isolated from the ISS nitrogen system by demating the rack umbilical.

Manual Valve
The GN2 manual valve is a Parker MB Series Ball Valve MB6XPFA-SSP-C3. The GN2 manual valve has dynamic soft seals made of PEEK (code 80546) and PFA (code 04913). If the soft seals were to leak, GN2 would be released to the cabin and the CIR rack would need to be isolated from the ISS nitrogen system by demating the rack umbilical.

GFE Quick Disconnect- Parker Stratoflex
The GN2 System also contains a GFE Parker Stratoflex quick disconnect that is not included in this analysis.

Hard Lines & Fittings
The GN2 system hard Lines & Fittings do not contain any soft seals.

Vacuum Exhaust System (VES)

Flexible Hoses – Aeroquip
The Flexible Hoses are a PTFE (code 00016) core with a stainless steel outer braid and stainless steel fittings. The Flexible Hoses do not contain any soft seals.

Quick Disconnect – Preece 51410 series
The QD has redundant Fluoroelastomer (code 05005) dynamic seals. These seals are only dynamic when mating or demating the QD. The QD cap contains the secondary seal for the QD in the un-coupled state. If both seals were to leak the CIR rack would need to be isolated from the ISS vent system by demating the rack umbilical.

GFE Quick Disconnects- Parker Stratoflex
The VES contains a GFE Parker Stratoflex quick disconnect that is not included in this analysis.

Hard Lines & Fittings
The VES system hard Lines & Fittings do not contain any soft seals.

Regulator
The regulator has PTFE (code 00016) dynamic and static seals. The regulator pressure is set on the ground and is not adjusted by the crew on-orbit. If the seals were to leak the CIR rack would need to be isolated from the ISS vent system by demating the rack umbilical.

Vacuum Resource System (VRS)
The CIR rack VRS system only contains a RUP QD that is capped off on the rack side of the RUP. The RUP QD is a GFE Parker Stratoflex quick disconnect that is not included in this analysis. The VRS does not contain any other soft seals.

1.2 CIR Pressure System Fatigue/Fracture Life Concern:

Reference CIR Fracture Control Summary Report, CIR-RPT-0342 Rev B.

FOMA
Chamber
The CIR chamber is a 100 liter pressure vessel rated for 135 psia MDP. The chamber pressure cycles are tracked as part of the FCF Sustaining Engineering activities. Safe life analysis was based on pre launch operational assumptions.

Risk 1:
Life extension to 2028 will exceed the operational assumptions identified in the Chamber safe-life analysis
Mitigation
The FCF team will assess chamber structure actual vs projected cycle life and update cycle projection through 2028 and perform updated safe-life analysis as required.

Chamber Windows
The CIR chamber utilizes ORU optical windows rated at 135 psia MDP. The total time at pressure is tracked as part of the FCF Sustaining Engineering activities. Safe life analysis was based on pre launch operational assumptions.

Risk 2:
Life extension to 2028 will exceed the operational assumptions identified in the Chamber Window safe-life analysis
Mitigation
The FCF team will assess chamber window actual vs projected time at pressure and update usage projection through 2028 and perform updated safe-life analysis as required.

ITCS
The CIR ITCS system MDP = 121 psia.

Flexible Hoses – Titeflex
Flex hoses are PTFE core with a Nomex outer braid and stainless steel fittings, designed with a burst pressure of 4.0 x MDP and proof pressure tested to 2.0 x MDP. The maximum diameter is 1/2 inch, which is under the 1.5 inch threshold defined in SSP 50699-04 section 3.1.3.3.

Hard Lines
The hard lines have a maximum diameter of 1/2 inch which is under the 1.5 inch threshold defined in SSP 50699-04 section 3.1.3.3. The hard lines have a burst pressure of 4.0 x MDP and proof pressure tested to 1.5 x MDP.

Valves, Quick Disconnects, and Fittings
All components have a minimum burst pressure of 4.0 x MDP and have been proof pressure tested at a system level to 1.5 MDP. These components do not require further analysis per SSP 50699-04 section 3.1.3.3.

Bellows
The CIR rack was launched with accumulator that has been disconnected when the rack umbilical's were mated, but is still mounted to the rack. The accumulator body (Belfab 63980A001) is GFE and has not been evaluated in this document.

Pressure Vessels
The CIR ITCS system does not contain any pressure vessels.

GN2

The CIR GN2 system MDP = 200 psia

Flexible Hoses - Aeroquip
The GN2 flex hose is a PTFE core with a stainless steel outer braid and stainless steel fittings, designed with a burst pressure of 4.0 x MDP and proof pressure tested to 1.5 x MDP. The maximum diameter is 3/8 inch, which is under the 1.5 inch threshold defined in SSP 50699-04 section 3.1.3.3.

Hard Lines
The GN2 hard lines have a maximum diameter of 3/8 inch which is under the 1.5 inch threshold defined in SSP 50699-04 section 3.1.3.3. The hard lines have a burst pressure of 4.0 x MDP and proof pressure tested to 1.5 x MDP.

Valves, Quick Disconnects, and Fittings
All components have a minimum burst pressure of 4.0 x MDP and have been proof pressure tested at a system level to 1.5 MDP. These components do not require further analysis per SSP 50699-04 section 3.1.3.3.

Bellows
The CIR GN2 system does not contain any bellows.

Pressure Vessels
The CIR GN2 system does not contain any pressure vessels.

VES

The CIR VES system MDP = 135 psia upstream of the regulator and MDP = 40 psia down stream of the regulator.

Flexible Hoses - Aeroquip
The VES flex hose is a PTFE core with a stainless steel outer braid and stainless steel fittings, designed with a burst pressure of 4.0 x MDP and proof pressure tested to 1.5 x MDP. The maximum diameter is 1/2 inch, which is under the 1.5 inch threshold defined in SSP 50699-04 section 3.1.3.3.

Hard Lines
The VES hard lines have a maximum diameter of 1/2 inch which is under the 1.5 inch threshold defined in SSP 50699-04 section 3.1.3.3. The hard lines have a burst pressure of 4.0 x MDP and proof pressure tested to 1.5 x MDP.

Valves, Quick Disconnects, and Fittings
All components have a minimum burst pressure of 4.0 x MDP and have been proof pressure tested at a system level to 1.5 MDP. These components do not require further analysis per SSP 50699-04 section 3.1.3.3.

Bellows
The CIR VES system does not contain any bellows.

Pressure Vessels
The CIR VES system does not contain any pressure vessels.

VRS

The CIR rack VRS system only contains a RUP QD that is capped off on the rack side of the RUP. The VRS system has a maximum diameter of 1.0 inch at the QD to fitting interface which is under the 1.5 inch threshold defined in SSP 50699-04 section 3.1.3.3. The VRS has a burst pressure of 4.0 x MDP and was proof pressure tested to 1.5 x MDP. The CIR VRS system MDP = 40psia.

1.3 CIR Critical Systems Not Replaceable (Non-ORU):

The CIR rack does not contain any critical systems.

1.4 CIR Non-ORU Limited Life Concerns:

ATCU Heat Exchanger

The CIR Air Thermal Control Unit (ATCU) is a ducted structural assembly including an air-water heat exchanger, a pair of cooling fans and a micro-controller. The heat exchanger is a custom Hughes-Treitler design that utilizes a MBF-30 braze compound exposed to station ITCS fluid. An analysis documented in FCF-PO-ANA-0002 done in 2006 using SSP 30573C fluid limits the heat exchanger life to 9.2 years due to braze joint corrosion when exposed to SSP 30573C fluid. Assessment is that the heat exchanger life is significantly greater than 9.2 years with either SSP 30573D or SSP 30573E fluid. The unit was never filled with SSP 30573C fluid.

Risk 3: ATCU Heat exchanger braze life will not meet 2028 life extension using SSP 30573D and SSP 30573E fluids

Mitigation:
The FCF team will perform an analysis of the ATCU heat-exchanger life using SSP 30573D and SSP 30573E fluids.

FOMA

The CIR Fluid Oxidizer Management Apparatus (FOMA) is a pneumatic system primarily composed of both ORU and non-ORU assemblies mounted to the CIR Optics Bench interconnected by hard tubing, flex hoses and electrical harnesses. The primary function of this system is to supply and vent a variety of gaseous mixtures and pressures ranges to the Combustion Chamber.

The CIR hazard reports FCF-C05, Release of Toxic By-products; FCF-C10, Rupture of Pressurized System; and FCF-C28, Inadvertent Venting of High Oxygen, Pre-mixed fuel, to the ISS Vent identify solenoid valves, relief valves and pressure regulators in the FOMA system as inhibits. The FOMA Control Unit (FCU) is a computer processor with integrated I/O that utilizes a set of pressure transducers to monitor and control the solenoid valve operations. The system also includes pressure switches and two independent Valve Timers which serve as controls to specific solenoid valves (normally closed) by interrupting electrical control power. Solenoid Valves: The FOMA solenoid valves are not classified as ORUs.

Solenoid Valves

All solenoid valve inhibits can be monitored for positively closure indication. Except for SV6, SV10, SV3, and SV13 this is accomplished with a pressure transducer in the line segment immediately downstream of the valve. In these cases closure is indicated by a stable pressure in the downstream segment. Valves SV6, SV10, SV3, and SV13 are located immediately upstream of pressure regulators with no intermediate transducer. In these cases valve closure is indicated by monitoring the transducer downstream of the regulator with the system operating below the regulator set-point. Not all of the closure indications occur as part of normal operations.

Risk 4:
Specific FOMA solenoid valve are not adequately monitor for internal leakage failure
Mitigation:
The FCF team will generate procedures to periodically establish positive closure indication of all FOMA solenoid valve inhibits

Pressure Regulators:

FOMA regulators are not classified as ORUs. All 8 pressure regulator inhibits can be monitored for proper regulator function as part of normal operations using pressure transducers in the line segment immediately downstream. Calibration of the pressure transducer monitors is address in the pressure transducer section below.

Relief Valves:

FOMA pressure reliefs are not classified as ORUs. Three Gas Chromatograph (GC) gas supply manifolds, check gas supply, helium gas supply and argon gas supply each utilize a pair of relief valves downstream of a supply regulator. None of the 6 reliefs are ever actuated as

part of nominal operations and currently there is no on-orbit mechanism to actuate these relief valves.

After 10 years of service it is difficult to justify the risk that these valves will fail to relieve as required. Even under the ideal environmental conditions in the FOMA these valves should be recertified to demonstrate proper function. Three options are available (1) exercise the relief valve; (2) replace the relief valves or (3) suspend GC operations – minor loss of capability. Initial evaluation is that exercising the relief is a feasible option, but would require development of on-orbit test equipment. One concept is a test bottle configured with a regulator and flex hose and the development of a crew procedures to attach and the test bottle to an existing QD port and operate the relief valve.

Risk 5:
FOMA GC supply manifold relief valves fail to relieve as required.
Mitigation:
The FCF team will perform a study to assess re-certification of the GC supply manifold relief valves.

Pressure Transducers:
FOMA pressure transducers are not classified as ORUs. The FOMA utilizes 14 pressure transducers as controls or monitors associated with the pressure system inhibits. 11 of these transducers are currently maintained under a yearly calibration cycle. The calibration process relies on a FOMA Calibration Unit (an ORU pressure transducer standard) that is calibrated on the ground and launched approximately once a year and returned to the ground at the end of its calibration period. The FCF project has 8 FOMA Calibration Units. This set is assessed as sufficient to sustain calibration operations through 2028.

3 pressure transducers (PT-19, PT-20 and PT-24) are located in the three GC gas supply manifolds (1 per manifold). These transducers are located downstream of the pressure regulator in each manifold and serve as monitors for proper function of the regulators. Currently these manifolds are not in use and there is no procedure for calibrating this set of transducers. Similar to the GC manifold relief valves there are three options available (1) calibration the PTs; (2) replace the PT's or (3) suspend GC operations – minor loss of capability. Initial evaluation is that calibrating the PTs is a feasible option with the development of a test bottle as described for use in exercising the relief valves.

Risk 6:
Out of calibration GC gas supply transducers PT-19, PT-20, or PT-24 fail to adequately monitor safety controls
Mitigation
The FCF team will perform a study to assess re-certification of the GC supply PT-19, PT-20, and PT-24.

Pressure Switches:
FOMA pressure switches are not classified as ORUs. The FOMA utilizes 8 pressure switches, 6 are high pressure limits associated with hazard controls, 2 are low pressure limits used to reset the Valve Timers after the combustion chamber is evacuated and are not hazard controls.

The 2 low pressure limits (PS-8 and PS-9) are exercised at intervals during nominal chamber evacuations and can be monitored for proper operation. Review of the pressure system shows that nominal ground procedures can be developed to actuate 5 of the 6 high pressure switch limits (PS-1, PS-2, PS-3, PS-4, and PS-7). The chamber high pressure limit PS-5, cannot be actuated under nominal conditions. This pressure switch may be accessible to the crew when the CIR rack door is open, however a custom wrench adapter tool may needed

Risk 7:
FOMA high pressure limit switches fail to control safety inhibits.
Mitigation
The FCF team will perform a study to implement spares and develop a procedure to remove and replace PS-5. The FCF team will develop ground procedure to periodically actuate PS-1, PS-2, PS-3, PS-4, and PS-7.

1.5 CIR Non-ORU Limited Cycle Life Concerns:

The CIR rack cycle life concerns are addressed in section 1.2, CIR Pressure System Fatigue/Fracture Life Concern

1.6 CIR ORU Sparing Concerns:

CIR on-orbit sparing plans are documented in FCF-PLN-4090, FCF Maintenance Plan. A preliminary assessment of sparing needs through 2028 has been developed but is not formally documented.

Risk 8:
CIR sparing plans do not meet life extension through 2028
Mitigation
Perform a formal sparing analysis for CIR based on projected utilization through 2028

1.7 CIR Life Concerns Unique to the Payload:

FOMA Reliability
The discussion in section 1.4 establishes the process for certifying safe design life and safe operating life of the FOMA using a run-to failure approach. However, the FOMA is a complex system primarily consisting of non-ORU elements as single point failure for to operational capability. Loss of the FOMA represents a major loss of capability in performing combustion science.

The FOMA can be divided into major sub-assemblies as shown in Table 1. Nominal operation of many of the FOMA sub-assemblies is required for mission success. These sub-assemblies include a variety of electrical and mechanical components that drive the overall MTBF of the FOMA. The list of components includes a variety of solenoid valves, manual valves, check valves, pressure regulators, pressure transducers, pressure switches and mass flow controllers. A reliability analysis of the FOMA is documented in CIR-ANA-0072 and calculates the

effective MTBF (applies assumed operational duty cycles) of the system to be 47,557 hours (5.4 years).

Risk 9
Low MTBF of the FOMA system and limited maintenance capacity leads to loss of major CIR capability
Mitigation:
Perform a FOMA reliability assessment to determine high risk failure points. Assess on-orbit remove and replace options for these failures.

2 FIR

The various components and sub-system of the FIR are discussed below to show that acceptable risks for life extension through 2028 can be achieved and that effective means exist for monitoring safety controls and inhibits for failures. This provides the rationale to classify these subsystems as run-to-failure.

2.1 FIR Pressure System Soft Seals Life Concerns:

The soft seal materials used in the FIR racks are overwhelmingly Fluoroelastomer and PTFE. These seals are all used in static or low duty cycle make/break configurations, over a benign temperature range and in a clean, non-corrosive environment. Reference FIR-LST-0142 Rev A, Material Identification/Usage List.

While these materials are generally not considered to have a life limit when in a controlled environment such as the ISS, each of the applications has been reviewed to determine if they are safe to run to failure.

The FIR contains 4 pressurizes sub-systems. The general discussion above is applicable to each of these sub-systems, The 4 FIR pressurized sub-systems are indented as follows:

Gaseous N2	GN2
ITCS	Intermediate Temperature Control System
VES	Vacuum Exhaust System
VRS	Vacuum Resource System

ITCS

The analysis of the FIR ITCS system is identical to the analysis of the CIR ITCS system detailed in section 1.1

Gaseous Nitrogen System (GN2)

The analysis of the FIR GN2 system is enveloped by the analysis of the CIR GN2 system detailed in section 1.2.2. The FIR GN2 system does not contain a flex hose or contain the Preece 942 series QD.

Vacuum Exhaust System (VES)

<u>Quick Disconnect – Preece 51410 series</u>

The QD has redundant Fluoroelastomer (code 05005) dynamic seals. These seals are only dynamic when mating or demating the QD. The QD cap contains the secondary seal for the QD in the un-coupled state. If both seals were to leak the FIR rack would need to be isolated from the ISS vent system by demating the rack umbilical.

<u>GFE Quick Disconnects- Parker Stratoflex</u>

The VES also contains a GFE Parker Stratoflex quick disconnect that is not included in this analysis.

Hard Lines & Fittings
The VES system hard Lines & Fittings do not contain any soft seals.

Vacuum Resource System (VRS)

Quick Disconnect – Preece 51410 series
The QD has redundant Fluoroelastomer (code 05005) dynamic seals. These seals are only dynamic when mating or demating the QD. The QD cap contains the secondary seal for the QD in the un-coupled state. If both seals were to leak the FIR rack would need to be isolated from the ISS vent system by demating the rack umbilical.

GFE Quick Disconnects- Parker Stratoflex
The VES also contains a GFE Parker Stratoflex quick disconnect that is not included in this analysis.

Hard Lines & Fittings
The VRS system hard Lines & Fittings do not contain any soft seals.

2.2 FIR Pressure System Fatigue/Fracture Life Concern:

Reference FIR Fracture Control Summary Report, FIR-RPT-0516 Rev C.

ITCS

The FIR ITCS system MDP = 121 psia.

Flexible Hoses – Titeflex
Flex hoses are PTFE core with a Nomex outer braid and stainless steel fittings, designed with a burst pressure of 4.0 x MDP and proof pressure tested to 2.0 x MDP. The maximum diameter is 1/2 inch, which is under the 1.5 inch threshold defined in SSP 50699-04 section 3.1.3.3.

Hard Lines
The hard lines have a maximum diameter of 1/2 inch which is under the 1.5 inch threshold defined in SSP 50699-04 section 3.1.3.3. The hard lines have a burst pressure of 4.0 x MDP and proof pressure tested to 1.5 x MDP.

Valves, Quick Disconnects, and Fittings
All components have a minimum burst pressure of 4.0 x MDP and have been proof pressure tested at a system level to 1.5 MDP. These components do not require further analysis per SSP 50699-04 section 3.1.3.3.

Bellows
The FIR rack was launched with accumulator that has been disconnected when the rack umbilical's were mated, but is still mounted to the rack. The accumulator body (Belfab 63980A001) is GFE and has not been evaluated in this document.

Pressure Vessels
The FIR ITCS system does not contain any pressure vessels.

GN2

The FIR GN2 system MDP = 200 psia

Flexible Hoses

The FIR GN2 system does not contain any flexible hoses.

Hard Lines

The GN2 hard lines have a maximum diameter of 3/8 inch which is under the 1.5 inch threshold defined in SSP 50699-04 section 3.1.3.3. The hard lines have a burst pressure of 4.0 x MDP and proof pressure tested to 1.5 x MDP.

Valves, Quick Disconnects, and Fittings

All components have a minimum burst pressure of 4.0 x MDP and have been proof pressure tested at a system level to 1.5 MDP. These components do not require further analysis per SSP 50699-04 section 3.1.3.3.

Bellows

The FIR GN2 system does not contain any bellows.

Pressure Vessels

The FIR GN2 system does not contain any pressure vessels.

VES

The FIR VES system MDP = 40 psia.

Flexible Hoses

The FIR VES system does not contain any flexible hoses.

Hard Lines

The VES hard lines have a maximum diameter of 1/2 inch which is under the 1.5 inch threshold defined in SSP 50699-04 section 3.1.3.3. The hard lines have a burst pressure of 4.0 x MDP and proof pressure tested to 1.5 x MDP.

Valves, Quick Disconnects, and Fittings

All components have a minimum burst pressure of 4.0 x MDP and have been proof pressure tested at a system level to 1.5 MDP. These components do not require further analysis per SSP 50699-04 section 3.1.3.3.

Bellows

The FIR VES system does not contain any bellows.

Pressure Vessels

The FIR VES system does not contain any pressure vessels.

VRS

The FIR VES system MDP = 40 psia.

Flexible Hoses
The FIR VRS system does not contain any flexible hoses.

Hard Lines
The VRS hard lines have a maximum diameter of 1/4 inch which is under the 1.5 inch threshold defined in SSP 50699-04 section 3.1.3.3. The hard lines have a burst pressure of 4.0 x MDP and proof pressure tested to 1.5 x MDP.

Valves, Quick Disconnects, and Fittings
All components have a minimum burst pressure of 4.0 x MDP and have been proof pressure tested at a system level to 1.5 MDP. These components do not require further analysis per SSP 50699-04 section 3.1.3.3.

Bellows
The FIR VRS system does not contain any bellows.

Pressure Vessels
The FIR VRS system does not contain any pressure vessels.

2.3 FIR Critical Systems Not Replaceable (Non-ORU):

The FIR rack does not contain any critical systems.

2.4 FIR Non-ORU Limited Life Concerns:

ATCU Heat Exchanger
The analysis of the FIR ATCU system is identical to the analysis of the CIR ATCU system detailed in section 1.4

2.5 FIR Non-ORU Limited Cycle Life Concerns:

The FIR rack does not have Non-ORU limited cycle life concerns.

2.6 FIR ORU Sparing Concerns:

FIR on-orbit sparing plans are documented in FCF-PLN-4090, FCF Maintenance Plan. A preliminary assessment of sparing needs through 2028 has been developed but is not formally documented.

Risk 10:
FIR sparing plans do not meet life extension through 2028
Mitigation
Perform a formal sparing analysis for FIR based on projected utilization through 2028

2.7 FIR Life Concerns Unique to the Payload:

ARIS
FIR utilizes the capability of the ISS provided ARIS system. This system is not maintained by the FCF project

Risk 11:
Overall reliability and sparing of the ARIS may not support life extension through 2028.
Mitigation:
FCF team will perform an assessment of operation impacts based on loss of ARIS capability.

Light Microscopy Microscope (LMM)

FIR utilizes the capability of the Light Microscopy Microscope (LMM). This sub-rack payload was built for a 5 year life cycle with limited maintenance and sparing. Current projects show that science utilization for the LMM could extend through the life of the ISS. As a sub-rack payload the LMM is not formally included as part of the ISS life extension certification plan.

Risk 12:
LMM reaches end-of-life with significant science utilization request unfulfilled.
Mitigation:
Include LMM as part of the FCF sparing analysis

3 SUMMARY OF IDENTIFIED RISKS:

The following section summarizes the risk and mitigations identified in sections 1 and 2.

Risk 1:
CIR only. Life extension to 2028 will exceed the operational assumptions identified in the Chamber safe-life analysis
Mitigation
The FCF team will assess chamber structure actual vs projected cycle life and update cycle projection through 2028 and perform updated safe-life analysis as required.

Risk 2:
CIR Only. Life extension to 2028 will exceed the operational assumptions identified in the Chamber Window safe-life analysis
Mitigation
The FCF team will assess chamber window actual vs. projected time at pressure and update usage projection through 2028 and perform updated safe-life analysis as required.

Risk 3:
CIR and FIR. ATCU Heat exchanger braze life not meet 2028 life extension using SSP 30573D and SSP 30573E fluids
Mitigation:
The FCF team will perform an analysis of the ATCU heat-exchanger life using SSP 30573D and SSP 30573E fluids.

Risk 4:
CIR only. Specific FOMA solenoid valve are not adequately monitor for internal leakage failure
Mitigation:
The FCF team will generate procedures to periodically establish positive closure indication of all FOMA solenoid valve inhibits

Risk 5:
CIR only FOMA GC supply manifold relief valves fail to relieve as required.
Mitigation:
The FCF team will perform a study to assess re-certification of the GC supply manifold relief valves.

Risk 6:
CIR only. Out of calibration GC gas supply transducers PT-19, PT-20, or PT-24 fail to adequately monitor safety controls
Mitigation
The FCF team will perform a study to assess re-certification of the GC supply PT-19, PT-20, and PT-24.

Risk 7:
CIR only. FOMA high pressure limit switches fail to control safety inhibits.
Mitigation
The FCF team will perform a study to implement spares and develop a procedure to remove and replace PS-5. The FCF team will develop ground procedure to periodically actuate PS-1, PS-2, PS-3, PS-4, and PS-7.

Risk 8:
CIR sparing plans do not meet life extension through 2028
Mitigation
Perform a formal sparing analysis for CIR based on projected utilization through 2028

Risk 9
CIR Only. Low MTBF of the FOMA system and limited maintenance capacity leads to loss of major CIR capability
Mitigation:
Perform a FOMA reliability assessment to determine high risk failure points. Assess on-orbit remove and replace options for these failures.

Risk 10:
FIR sparing plans do not meet life extension through 2028
Mitigation
Perform a formal sparing analysis for FIR based on projected utilization through 2028

Risk 11:
FIR Only. Overall reliability and sparing of the ARIS may not support life extension through 2028.
Mitigation:
FCF team will perform an assessment of operation impacts based on loss of ARIS capability

Risk 12:
FIR Only. LMM reaches end-of-life with significant science utilization request unfulfilled.
Mitigation:
Include LMM as part of the FCF sparing analysis