Seedling Growth Experiments (SG-1 and SG-2) Experiment Status

Current Status of the ARC EMCS Payloads

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Lockheed Martin

POIWG #35

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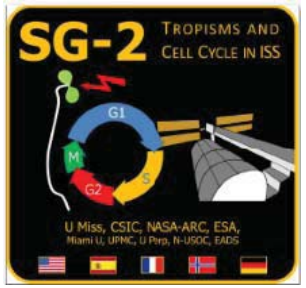


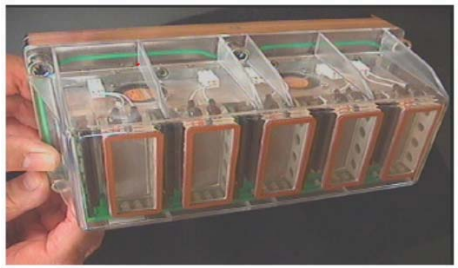
Experiment Hardware

All the ARC ISS Space Biology Project EMCS Experiments use the same hardware suite.

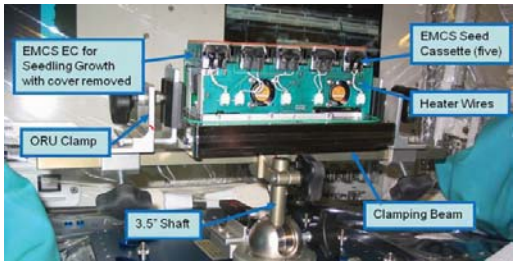
- Proven ***highly successful*** starting with the Tropi series of experiments in 2006.

EMCS Facility

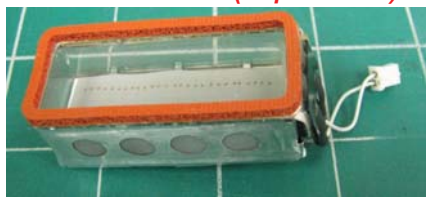
EMCS Experiment Containers (ECs)



MWA set up for Sample Processing with ARC-developed EUE



ARC Cassettes (5 per EC)



EMCS Cold Stowage Bag with Cassettes

Hardware Capabilities for Science

The combination of the EMCS facility with the ARC-developed EUE provides tremendous flexibility for biological investigations.

EMCS

- Automated experiment scheduling capability.
- Controls atmospheric composition, temperature, and humidity.
- Provides artificial gravity levels with 2 independent rotors (0g, 1g, etc.).
- Each rotor holds 4 Experiment Containers.
- Flexible imaging capability.

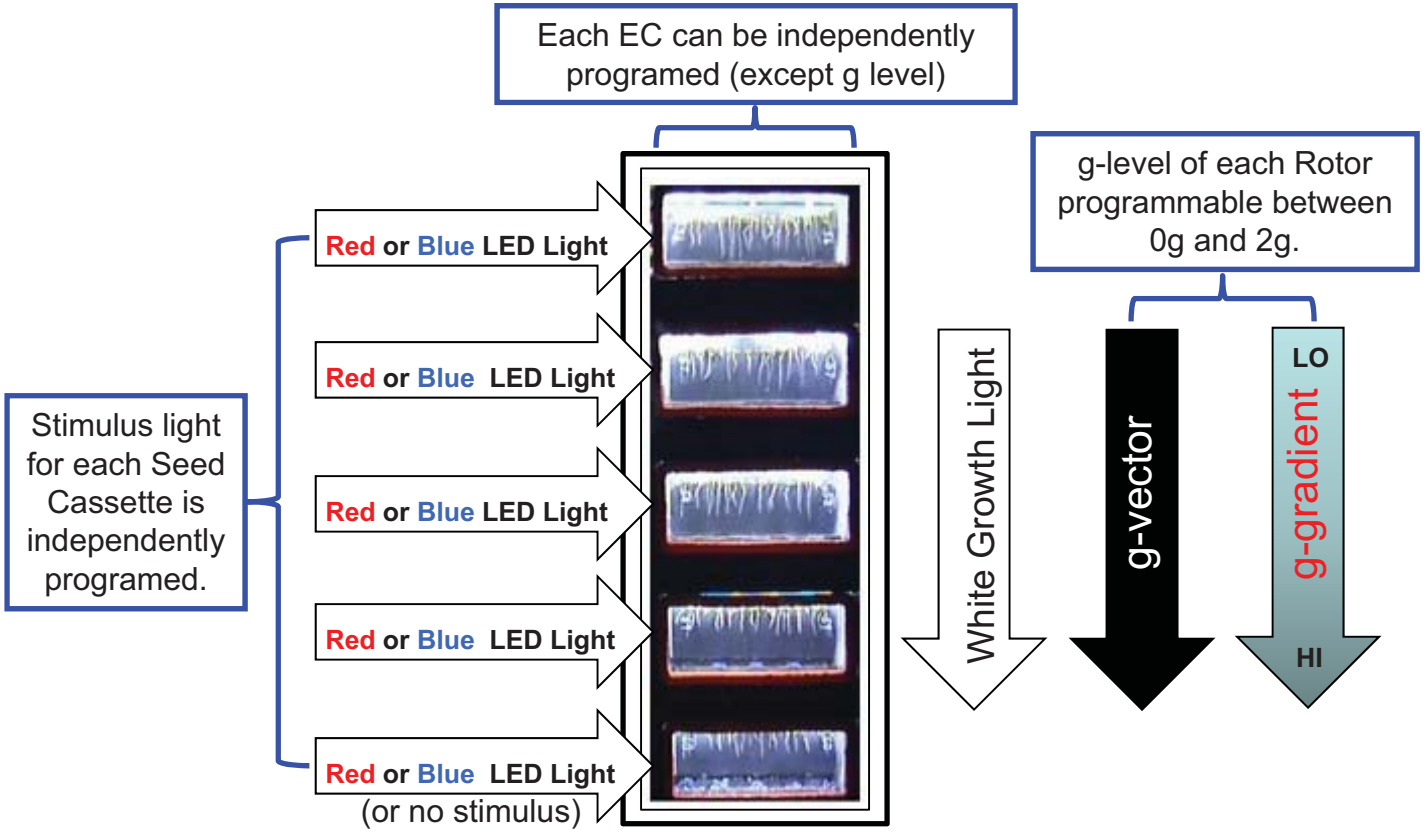
ARC EUE

- Interface between EC and ARC-developed Cassettes.
- Watering system for initiating experiment.
- Provides White LED growth lighting (parallel to rotor g vector).
- Provides Red and/or Blue LED stimulus lighting (normal to g vector).

ARC Seed Cassettes

- Miniaturized growth chambers, 5 per EC.
- Typically planted with 14 – 20 seeds/cassette for botanical experiments
- Can also support other model organisms.

Science Variables



- Each Cassette can contain a specific genetic mutant or model organism.
- Image data for analysis of responses downlinked in near real time.
- Cassettes frozen at end of run to preserve RNA, genomics, proteomics etc.

The Seedling Growth Experiments

BACKGROUND

The Seed Growth Series is the result of a cooperative agreement. between NASA and ESA to combine the proposals of a NASA PI and an ESA PI to maximize science return.

- NASA PI: Dr. John Kiss.
  - Emphasis on plant tropic responses using EMCS Image Data.
- ESA PI: Dr. Javier Medina.
  - Emphasis on structure and biochemistry using frozen samples.

Three experiments are in development SG-1, SG-2 and SG-3.

- SG-1 & SG-2 are NASA-led.
- SG-3 is ESA-led.

A fourth experiment (SG-4) is optional and may be developed, if agreed by the parties, to extend the investigation based on results obtained.

Seedling Growth-1 and -2

EXPERIMENT PERSONNEL

Principal Investigators:	**John Z. Kiss, Ph.D., University of Mississippi, MS (NASA)** **F. Javier Medina, Ph.D., CIB-CSIC, Madrid, Spain (ESA)**	
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NASA POC	**Jeffrey Smith** **(650) 604-0880**	***Jeffrey.D.Smith@nasa.gov***

Seedling Growth-1 and -2

ACKNOWLEDGMENTS

N-USOC

Knut Fossum (Project Manager)
Mona Schiefloe (SG-1 ExAM)
Liz Helena Coelho (SG-2 ExAM)

Ops and Ground Controllers
Gjert Aanes
Brit-Eli Danielsen
Knut Olav Helleseng
Karl Eric Hancock
Tore Martin Hauan
Irene Karoliussen
Basit Mohammad

EADS/Astrium

Maria Birlem (SG-2 EMCS PIM)
Reinhard Born
Thomas Niedermaier (SG-1 EMCS PIM)

MSFC POIC SUPPORT

Amy Haas (SG-1 & 2 PIM)
Kevin Hargrave (Ops Lead)
Chris Traylor (PARC)

And many more!

Seedling Growth-1

EXPERIMENT SUMMARY

The objective of the Seedling Growth-1 experiment is to determine how gravity and light responses in plants influence each other and to better understand the cellular signaling mechanisms involved in plant tropisms.

Launch: SpaceX-2, March 1st, 2013
Operations: Increment 35

- All four planned 6-day runs were completed successfully
  - Run 1 - Mar 22 - 28, 2013
  - Run 2 - May 2 - 8 *(delayed by EMCS Rotor Belt Replacement)*
  - Run 3 - May 10 -17
  - Run 4 - May 18 -24
- All planned images of seedling growth and tropic responses were successfully captured and are being analyzed by the PIs
- Seed cassettes were transferred to MELFI at the end of each run
- Frozen samples and empty ECs are planned to return on SpX-3 (March 2014)
  - ECs *must* be recovered at early destow to refurbish for SpX-4 (SG-2)
  - Frozen samples return to JSC in GLACIER
  - ESA Representative will receive samples from JSC Cold Stowage Group and arrange transport to ESA PI lab in Spain

Seedling Growth-2

EXPERIMENT SUMMARY

The objective of the Seedling Growth-2 experiment is to determine how gravity and light responses in plants influence each other and to determine the combined influences of light and gravity on plant development through the identification of changes in the mechanisms and regulation of essential cellular functions. These experiments rely in a large part on the use of known Arabidopsis thaliana mutant plants that are genetically altered in specific light-, auxin- or cell division- regulated processes

Launch:	SpaceX-4, June 2014 (TBC)
Operations:	Increment 39/40

- Three 6-day runs are planned:
  - Run 1 - Continuation of Dr Kiss' SG-1 objectives - stimulus at 0.5 g
    - Four ECs, uses 1 EMCS rotor only
  - Run 2 - Continuation of Dr Kiss' SG-1 objectives - stimulus at 0.8 g
    - Four ECs, uses 1 EMCS rotor only
  - Run 3 - Primarily supports Dr. Medina's objectives - at 0 and 1.0 g
    - Eight ECs, uses both EMCS rotors.
- Images of seedling growth and tropic responses will be captured for PI's analysis
- Seed cassettes will be transferred to MELFI at the end of each run
- Frozen samples and empty ECs are planned to return on SpX-5 (October 2014,TBC)
  - Frozen samples return to JSC in GLACIER
  - ESA Representative will receive samples from JSC Cold Stowage Group and arrange transport to ESA PI lab in Spain

Seedling Growth-2

CREW ACTIVITIES

On-orbit activities are similar or identical to Seedling Growth 1 Experiment.

Crew Activities - minor updates only:

Procedure titles
Execution notes
On Board Training

- EMCS Gas Valve open/close
- Load and unload ECs in and out of EMCS for each experiment run.
- MWA and video set up and configure.
- Remove seed cassettes from the ECs at end of each experiment run.
- Place seed cassettes into the EMCS Cold Stowage Bags and insert into MELFI.
- Place EMCS Cold Stowage Bags from MELFI into Double Cold Bag for on orbit transfer to GLACIER for return to Earth.

Seedling Growth-2

GROUND COMMANDING

- All commanding is performed by the EMCS controllers at N-USOC.
- Commanding is required for EMCS file uplink, power up and power down, hydration, video initiation and downlink.
- Nominally, once initiated, the experiment sequence is largely controlled by EMCS scheduling software.
  - Command windows are requested to allow correction of any off-nominal conditions.
  - Data telemetry and digital images are monitored at N-USOC and ARC MMOC.
- Contingency commanding windows are required to react to off-nominal situations.
  - Critical timing of scheduled experiment events requires ground controllers to be able to react to off-nominal situations rapidly.

Seedling Growth-2

Sample Processing by Crew at the end of each experiment run

- Set up MWA and video camera (over the shoulder view).
- ECs/Seed Cassettes removed from EMCS rotor and transferred to MWA.
- Seed Cassettes removed from EC/EUE, placed in EMCS Cold Bags.
- Cold Bags inserted into MELFI – Time constraints from rotor stop to MELFI insertion.
  - Run 1 & 2 and Run 3, Rotor B less than 45 min
  - Run 3, Rotor A, less than 1hr 45 min

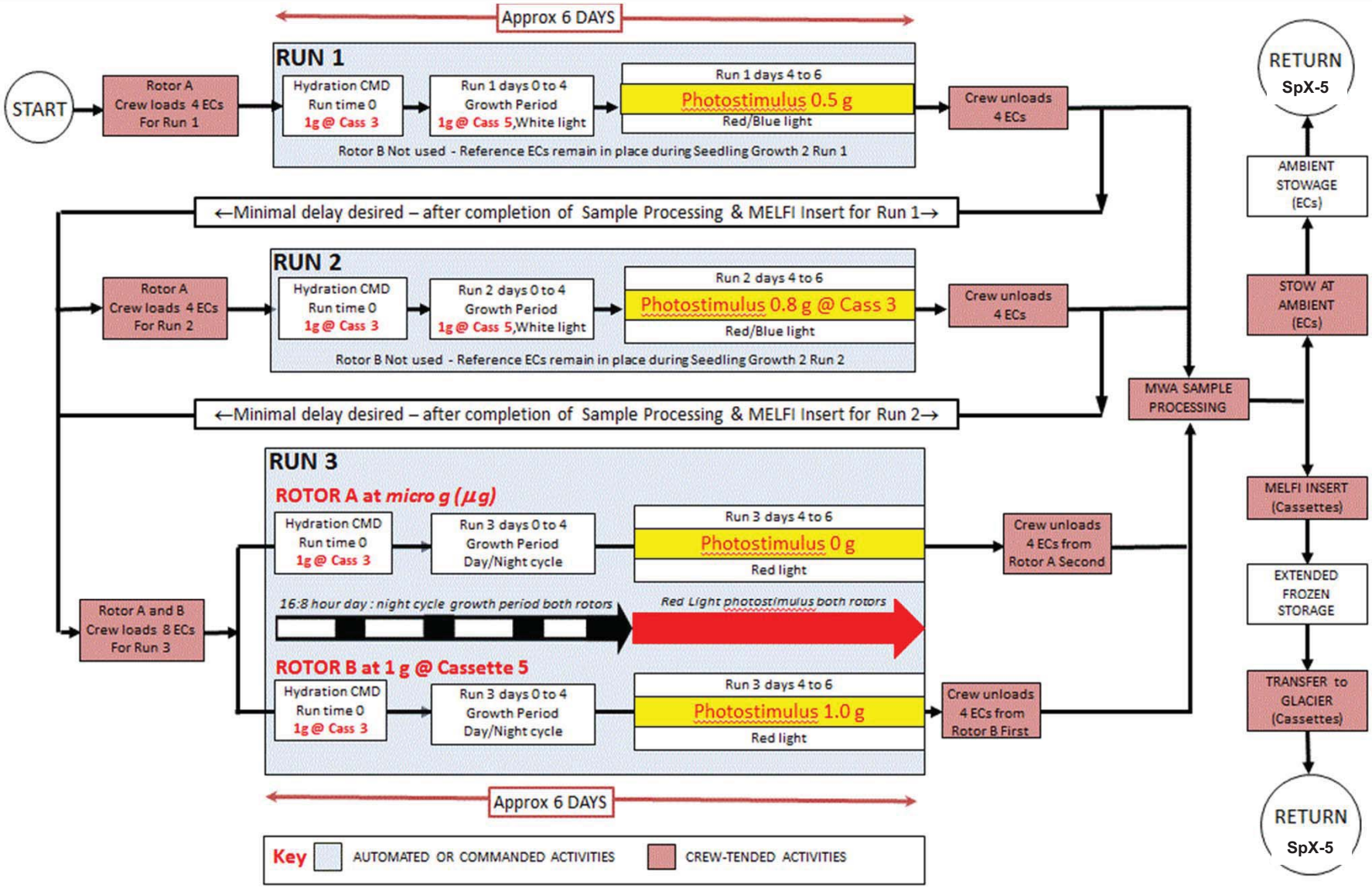
Sample Processing by Crew for return to Earth

- Transfer samples from MELFI to cooled double cold bag on-orbit transfer.
- Transfer samples from double cold bag to GLACIER on vehicle for return to Earth.
- For any transfer, the total time that samples can be exposed to ambient temperature must be less than three minutes to avoid sample degradation.
- Activity requires two crew members to ensure this limit is met.

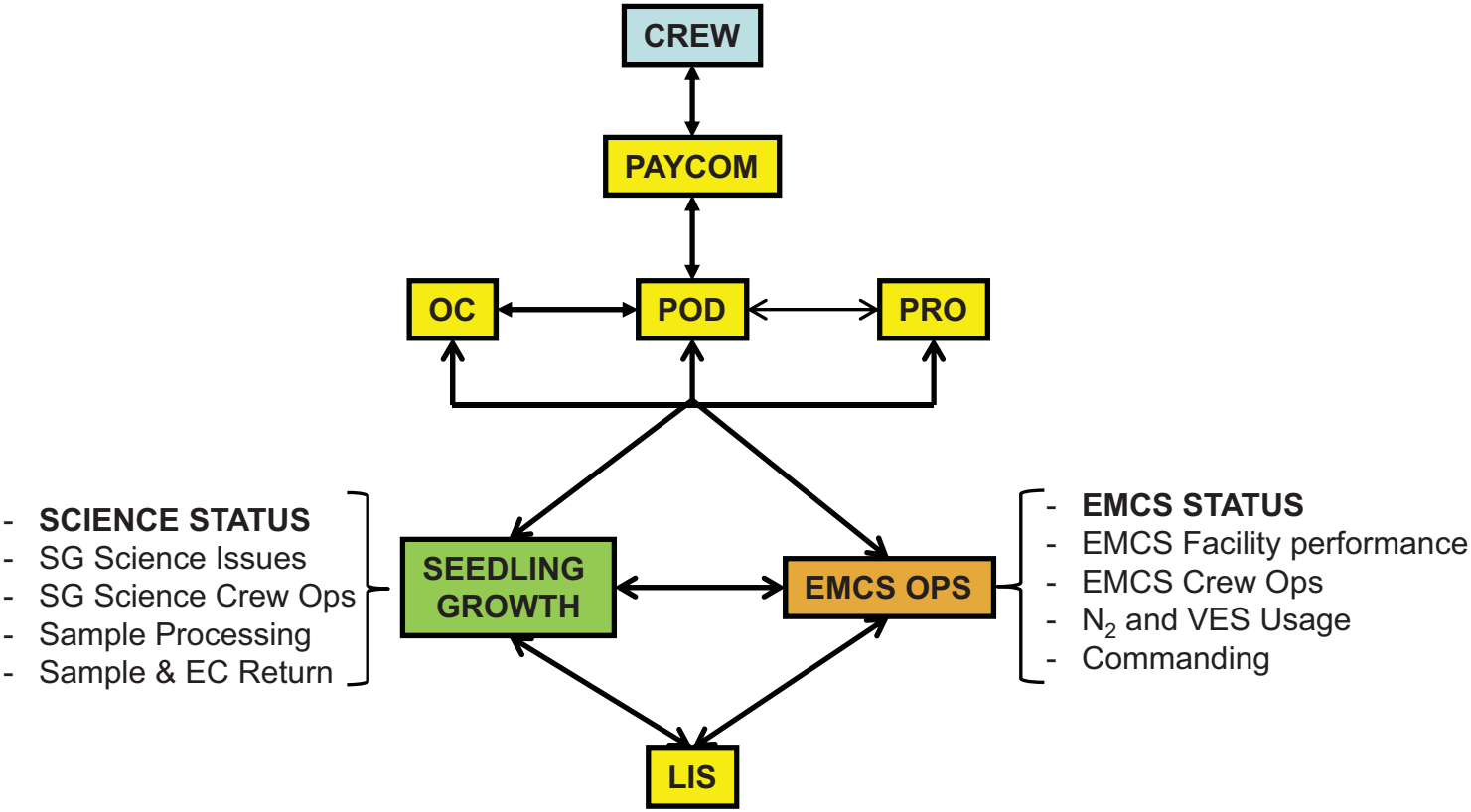
Seedling Growth-2

EXPERIMENT CONSTRAINTS

- Experiment must be started no later than 1.0 month after arrival at the ISS.
- 3 six-day experiment runs are planned for this experiment. Ideally, runs will be performed consecutively, back to back.
- After the crew loads ECs into EMCS, the experiment run is initiated by ground commanding.
- Samples (Seed Cassettes) are collected at the end of each 6-day run and stored in MELFI.
- In flight seedling images provided to Dr. Kiss and Dr. Medina near real time.
  - Via FTP protocol from N-USOC server
- Return on SpaceX-3: Frozen samples in GLACIER; ECs at ambient.
  - After Splash down, Cold Stowage Group transfers samples to JSC, maintaining -80°C.
  - At JSC, samples will be turned over to ESA rep for shipment to ESA PI in Madrid, Spain.
  - ECs and EUE turned over to ARC representative. Location and timing TBD.
    - Likely Early Recovery needed in CA to support hardware refurbishment


Approx 6 DAYS
START
Rotor A
Crew loads 4 ECs
For Run 1
RUN 1
Hydration CMD
Run time 0
1g @ Cass 3
Run 1 days 0 to 4
Growth Period
1g @ Cass 5,White light
Run 1 days 4 to 6
Photostimulus 0.5 g
Red/Blue light
Rotor B Not used - Reference ECs remain in place during Seedling Growth 2 Run 1
Crew unloads
4 ECs
←Minimal delay desired – after completion of Sample Processing & MELFI Insert for Run 1→
Rotor A
Crew loads 4 ECs
For Run 2
RUN 2
Hydration CMD
Run time 0
1g @ Cass 3
Run 2 days 0 to 4
Growth Period
1g @ Cass 5,White light
Run 2 days 4 to 6
Photostimulus 0.8 g @ Cass 3
Red/Blue light
Rotor B Not used - Reference ECs remain in place during Seedling Growth 2 Run 2
Crew unloads
4 ECs
←Minimal delay desired – after completion of Sample Processing & MELFI Insert for Run 2→
MWA SAMPLE PROCESSING
RUN 3
ROTOR A at micro g (μg)
Rotor A and B
Crew loads 8 ECs
For Run 3
Hydration CMD
Run time 0
1g @ Cass 3
Run 3 days 0 to 4
Growth Period
Day/Night cycle
Run 3 days 4 to 6
Photostimulus 0 g
Red light
Crew unloads
4 ECs from
Rotor A Second
16:8 hour day : night cycle growth period both rotors
Red Light photostimulus both rotors
ROTOR B at 1 g @ Cassette 5
Hydration CMD
Run time 0
1g @ Cass 3
Run 3 days 0 to 4
Growth Period
Day/Night cycle
Run 3 days 4 to 6
Photostimulus 1.0 g
Red light
Crew unloads
4 ECs from
Rotor B First
Approx 6 DAYS
Key
AUTOMATED OR COMMANDED ACTIVITIES
CREW-TENDED ACTIVITIES
RETURN
SpX-5
AMBIENT STOWAGE (ECs)
STOW AT AMBIENT (ECs)
MELFI INSERT (Cassettes)
EXTENDED FROZEN STORAGE
TRANSFER to GLACIER (Cassettes)
RETURN
SpX-5

Seedling Growth-2 Realtime Operations Interface



Seedling Growth-2 Realtime Operations Interface

Real Time Contacts

N-USOC (Console coverage 24/7 during experiment runs)

Project Manager Carina Helle Berg carina.berg@ciris.no
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ARC (Console coverage during crew operations only)

Project Manager Marianne Steele Marianne.K.Steele@nasa.gov
Deputy Project Manager David Heathcote david.g.heathcote@nasa.gov

Seedling Growth-2

SCHEDULE 2013 – 2014

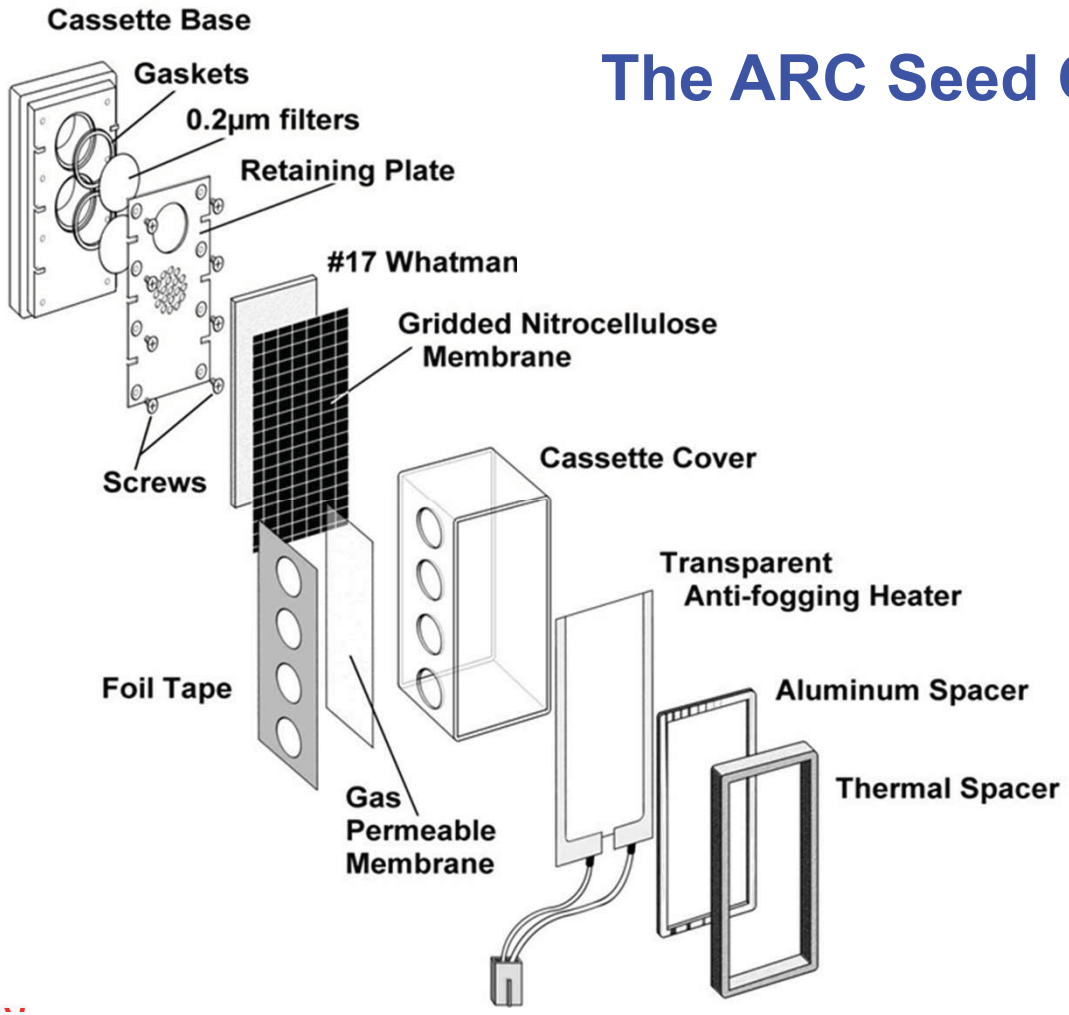
- Schedule Test N-USOC *September 30th to October 8th, 2013* √ *complete*
- OVT/EVT N-USOC *December 9th to 16th, 2013* √ *complete*
- Return of SG-1 EC/EUE – SpaceX-3 *March 2014*
- MSFC Sims *TBD, Planned*
- Flight Build – *May, 2014*
- Launch – SpaceX-4, *NET June 6th, 2014*
- On-Orbit Operations – ASAP after on dock – 3 x 6 day runs, *June/July 2014*
- Return Seed Cassettes and EC/EUE Assemblies – SpaceX-5, *October 2014*

Acronyms

ARC	Ames Research Center
ASAP	As Soon as Possible
EADS	European Aeronautic Defense & Space Company
EC	Experiment Container
EMCS	European Modular Cultivation System
ESA	European Space Agency
EUE	Experiment Unique Equipment
EVT	Experiment Verification Test
ExAM	Experiment Activity Manager (N-USOC)
FTP	File Transfer Protocol
GLACIER	General Laboratory Active Cryogenic ISS Experiment Refrigerator
IPLAT	ISS Payload Label Approval Team
ISS	International Space Station
JSC	Johnson Space Center
MELFI	Minus Eighty Laboratory Freezer for ISS
MMOC	Multi Mission Operations Center
MSFC	Marshall Space Flight Center
MWA	Maintenance Work Ared
NASA	National Aeronautics and Space Agency
NET	No Earlier Than
N-USOC	Norwegian User Support Operations Center
OVT	Operations Verification Test
PARC	Payload Activity Requirements Coordinator
PD	Payload Developer
PI	Principal Investigator
PIM	Payload Intergration Manager
POC	Point of Contact
SG-1	Seedling Growth-1 experiment
SpX	Space-X
TBC	To Be Confirmed
TBD	To Be Determined

Back-up Slides

The ARC Seed Cassette



Back-up Slides

Seed Cassette Images