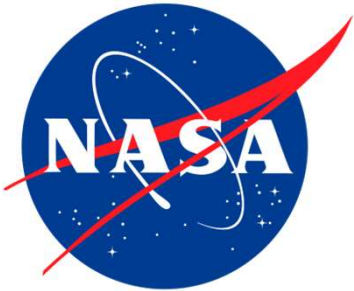


Ground Test Validations for Uncrewed Dormancy Preparation and Recovery

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Track 303-D



Agenda



- Introduction
- Shutdown Considerations
- Success Criteria
- Experimental Systems for Dormancy
- Flushing Considerations
- Dormancy Quantification
- Urine Separator
- Water Condensate Separator
- Water Recovery System Filters
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Introduction



Uncrewed dormancy is a concern from a biofilm and biological growth perspective upon restart. Although aspects of dormancy have been examined, a consolidated attempt at examining dormancy for specific hardware hasn't been looked at until now. This paper serves as an update to current efforts by the Marshall Space Flight Center, and the Center for Biofilm Engineering to determine uncrewed dormancy behavior and procedures.





Shutdown Considerations

- Flushing the wastewater system frequently discussed.
 - Flushing with product water containing biocide?
 - Do we monitor TOC or other indicators?
 - Will flushing dislodge biomass and clog downstream equipment?
- Automated maintenance or cycling during dormancy
 - Feasible to power up and cycle the wastewater system?
 - Automated release of biocides during dormancy period?
- Dry-out strategy
 - Worth complexity and extra storage space to store vital water supplies?
 - Residual moisture could favor certain microorganisms.

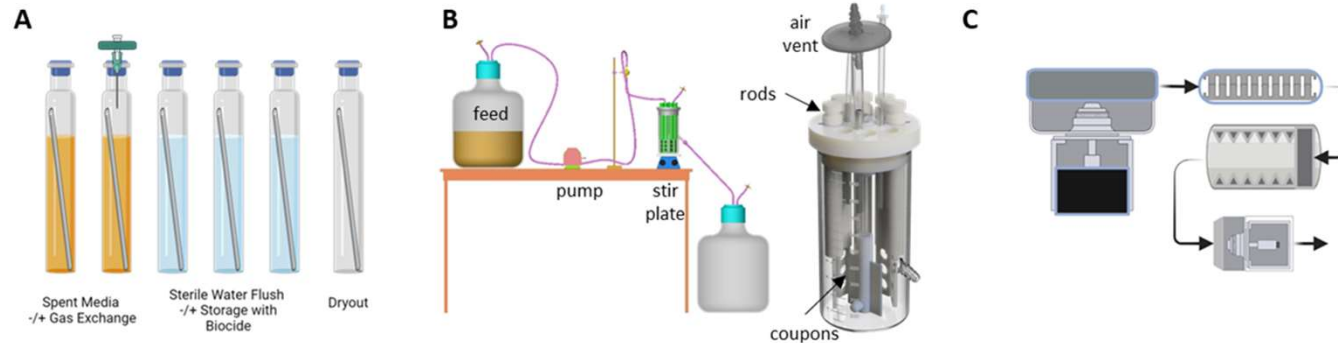


Success Criteria

Dormancy plan involves minimal maintenance and resources.
What is the success criteria?

- Microbial presence and survival.
 - Measuring the biofilm potential exiting dormancy
 - Do we target specific larger biomass organisms?
- Material Compatibility
 - Assessment of microbial induced corrosion (MIC)
- Biocide efficacy and compatibility
 - Biocide levels higher than normal to knock out microbial growth
 - Maintenance of a biocide residual
 - Development of biocide resistance by organisms

Experimental Systems for Dormancy



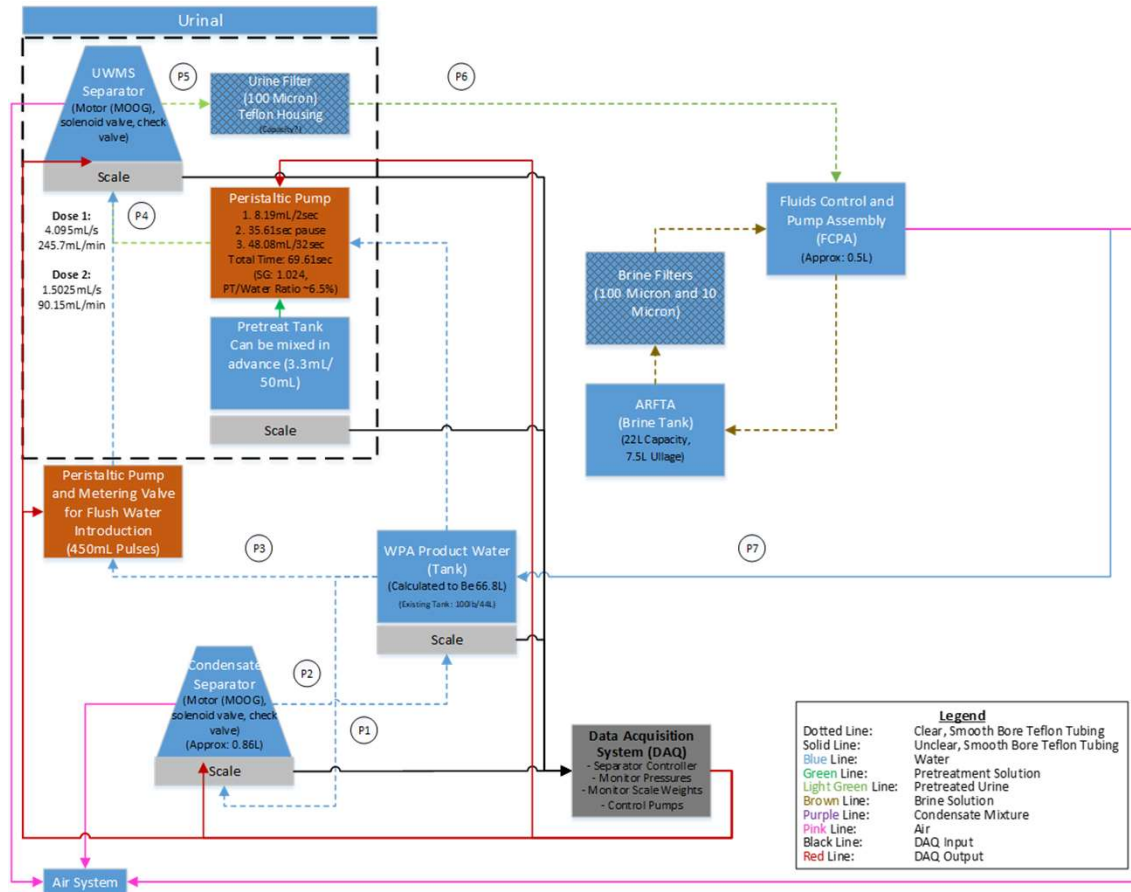
Advantages: • Many conditions for comparison • Time-course during dormancy possible with destructive sampling • Controlled headspace (easy to assess anaerobic conditions) • Long time course (weeks to years) • Inconel strips for material compatibility	Advantages: • Commercially available reactor system with ASTM method • 24 Inconel coupons in 8 rods for time-course (prior to/after dormancy) • Continuous flow system • Parallel reactors for several conditions for comparison • Replication possible in serial experiments • Intermediate time course (weeks to months)	Advantages: • Complex and relevant geometry allows for identification of problematic regions and points of failure • Relevant material on all internal surfaces with appropriate surface area to volume • Continuous flow system • Intermediate to long time course (weeks to years)
Limitations: • Destructive sampling • Batch System (no flow) • Limited replication unless staggered start in parallel	Limitations: • Sampling during dormancy will disturb dormant conditions • Large headspace in standard configuration	Limitation: • Sampling during dormancy will disturb dormant conditions • Limited conditions for comparison • Replication may take years



Flushing Considerations

- An adequate flushing regime has not been determined.
- MSFC is seeking to determine adequate flushing volumes and procedures for the urine separator, condensate separator and various filter assemblies
- Current proposed MSFC flushing regime
 - Flushing with iodinated product water (3ppm) at 10 times the volume
 - Flow rate of approximately 13 lb/hr
- CBE Flushing Procedure
 - Current total volume was poured off then a total volume of sterile water was introduced, and that sterile water was then poured off

Dormancy Quantification

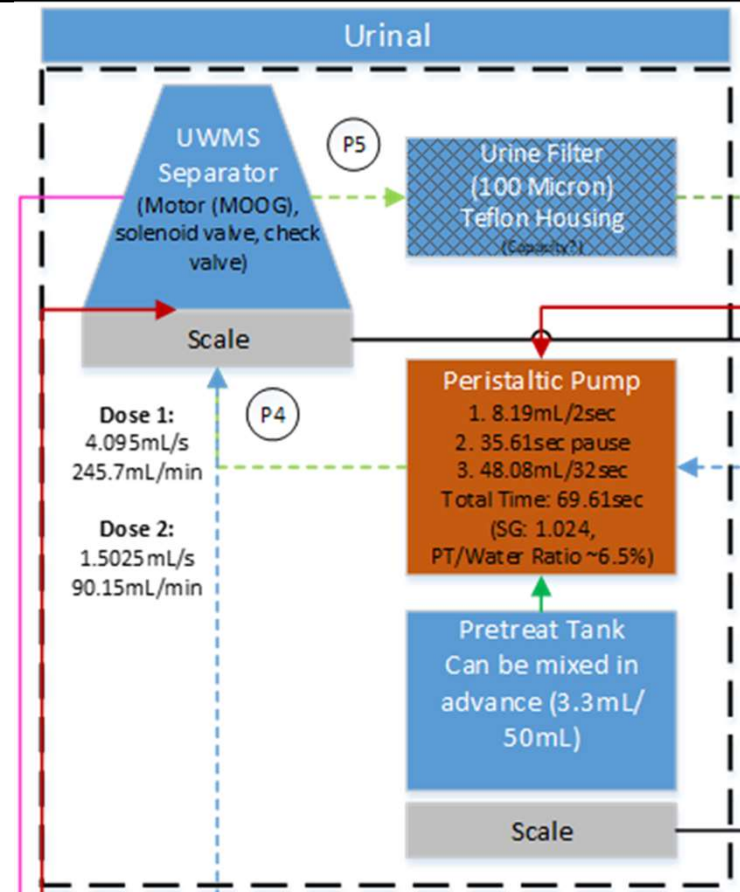


- MSFC is producing hardware for the UWMS urine separator, various filters, and the condensate separator.
- Equipment is being produced for high fidelity internal geometry only.

Urine Separator

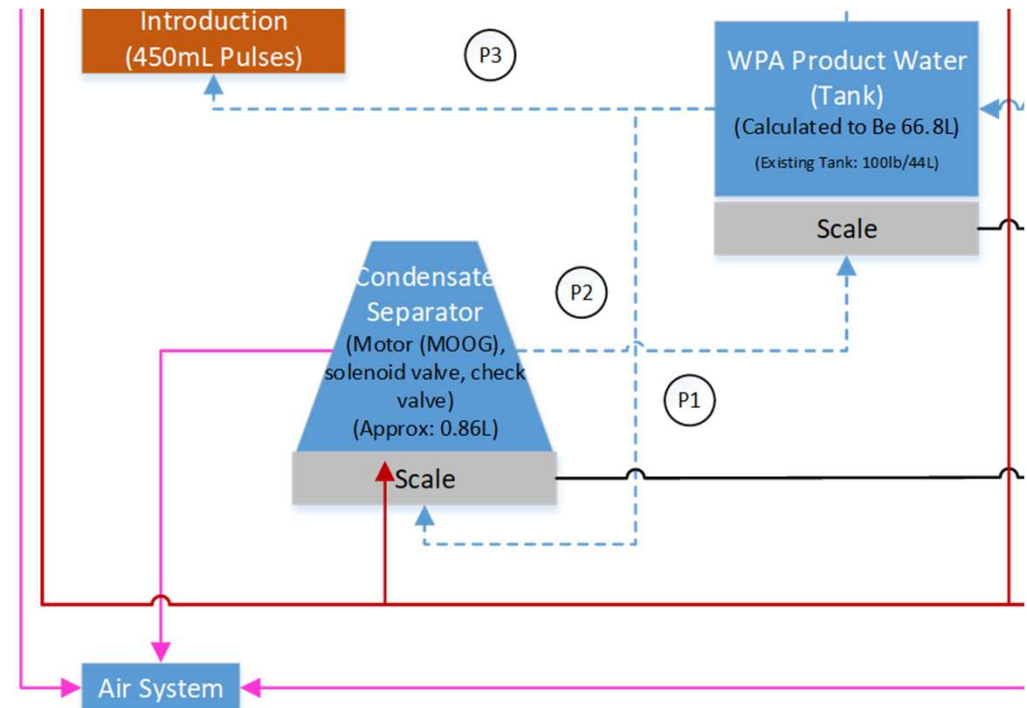


- MSFC has been producing a high-fidelity internal geometry apparatus.
 - Due to the hexavalent chromium pretreat, titanium must be utilized
 - A collaboration with the Army allowed for these 3D printed pieces to be created, machined, and hot isostatic pressing for temperature treatment.
- Remaining work
 - Welding the 3D printed material together to form the separator
 - Gearbox assembly mated to the part
- Urine Separator Gearbox Design
 - Obtaining an original gearbox was unfeasible
 - Grasshopper visual programming language assisted to create algorithms for gear sizing and configuration



Water Condensate Separator

- Water condensate contributes to the biofilm problem in the wastewater tank, and is a major dormancy concern
- MSFC has been producing a high-fidelity internal geometry apparatus.
 - Titanium was utilized, as the material was already being used for the urine separator and aluminum is difficult to 3D print.
 - While internal geometry will be high fidelity worth discussing difference of internal material.
- Remaining work
 - Welding the 3D printed material together to form the separator
 - Non-3D printed machined pieces must be finished and integrated into the build
 - Motor assembly mated to the part





Water Recovery System Filters

- Urine brine processing filter, purge gas filter, and urine filter needed
- MSFC has been producing a urine filter housing
 - Due to hexavalent chromium compatibility, the exterior urine filter housing is polyvinylidene difluoride (PVDF)
 - ISS filter cartridge (Pall 100 micron filter) contained within this housing
 - Middle flange added to allow for filter examination
- Purge Gas Filter Acquired

Questions?

Thank you for your time!

