



Chemical Reactivity of Lunar Dust Relevant to Humans

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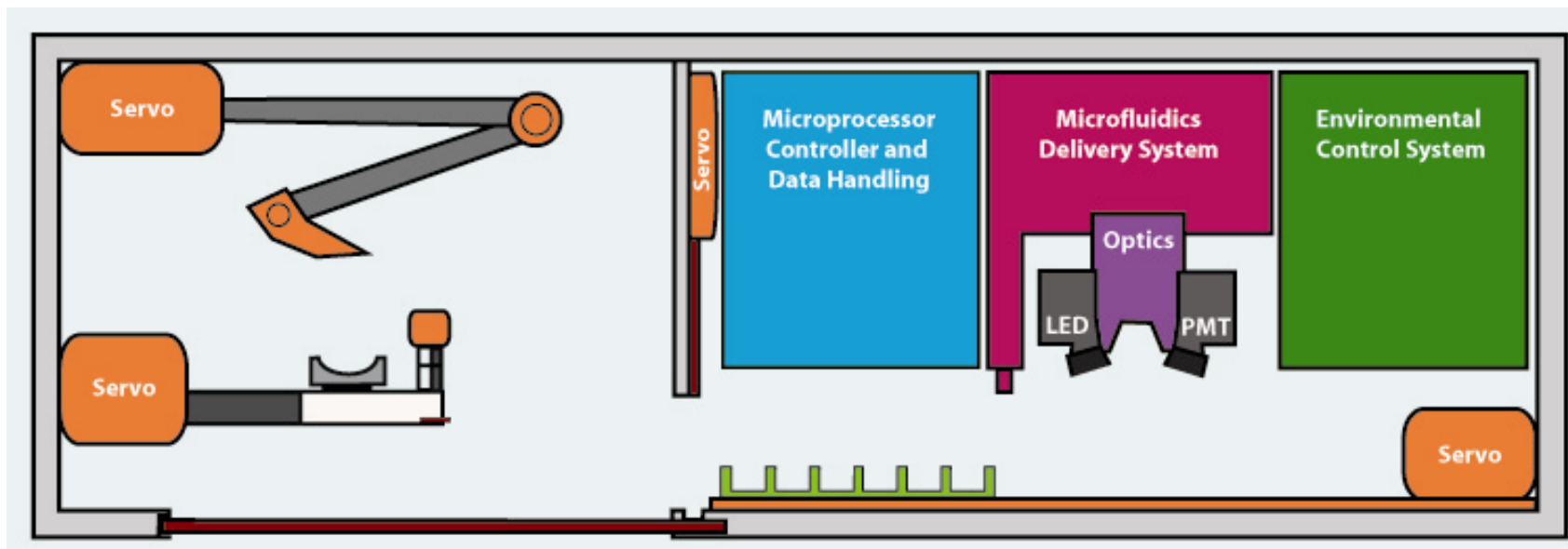


**LEAG / ILEWG / SRR
October 29, 2008**

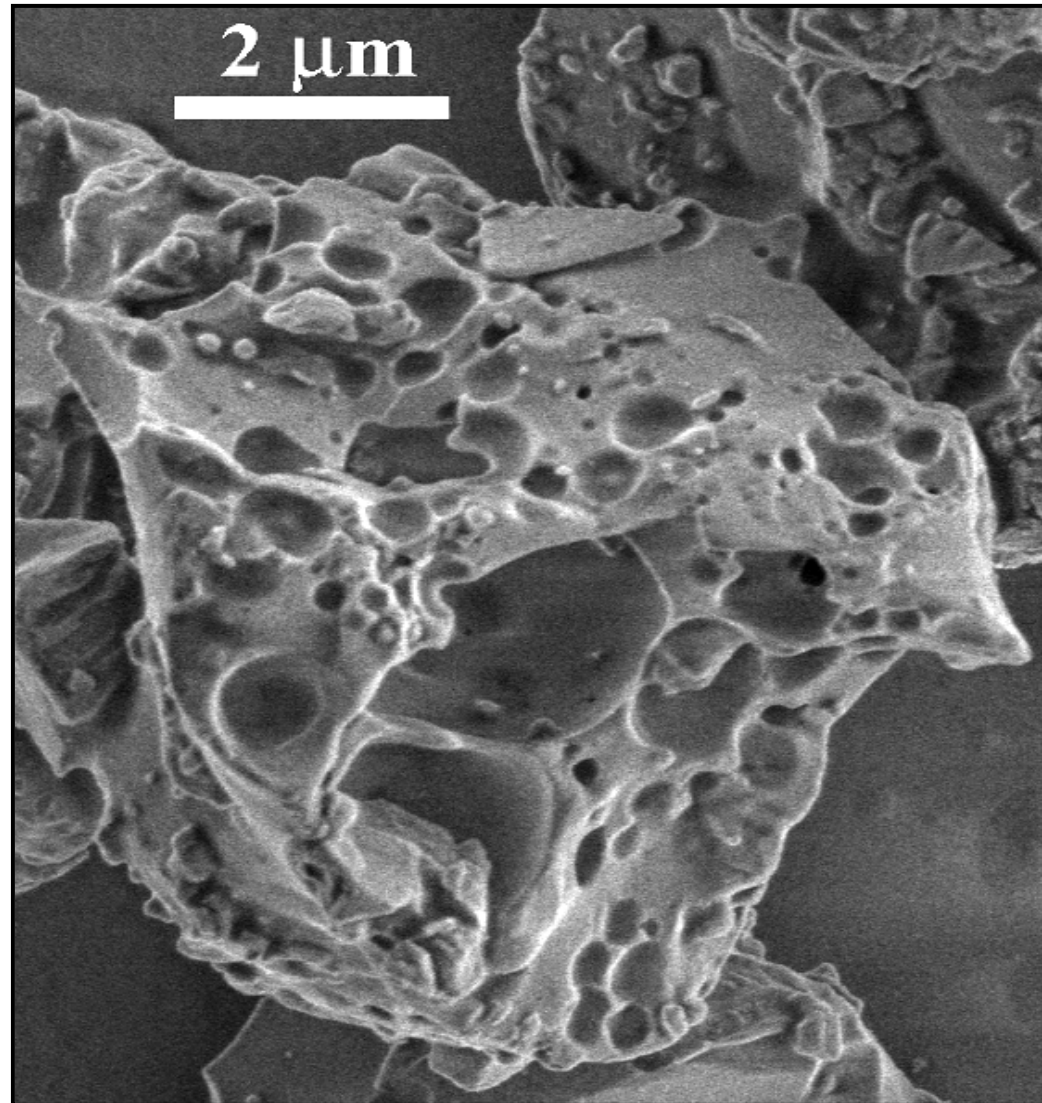
Our Answer to The Question

What technologies need to be developed now for human return to the Moon (and beyond)?

LunaChem – an instrument designed to test the chemical reactivity of lunar dust.



The Problem...



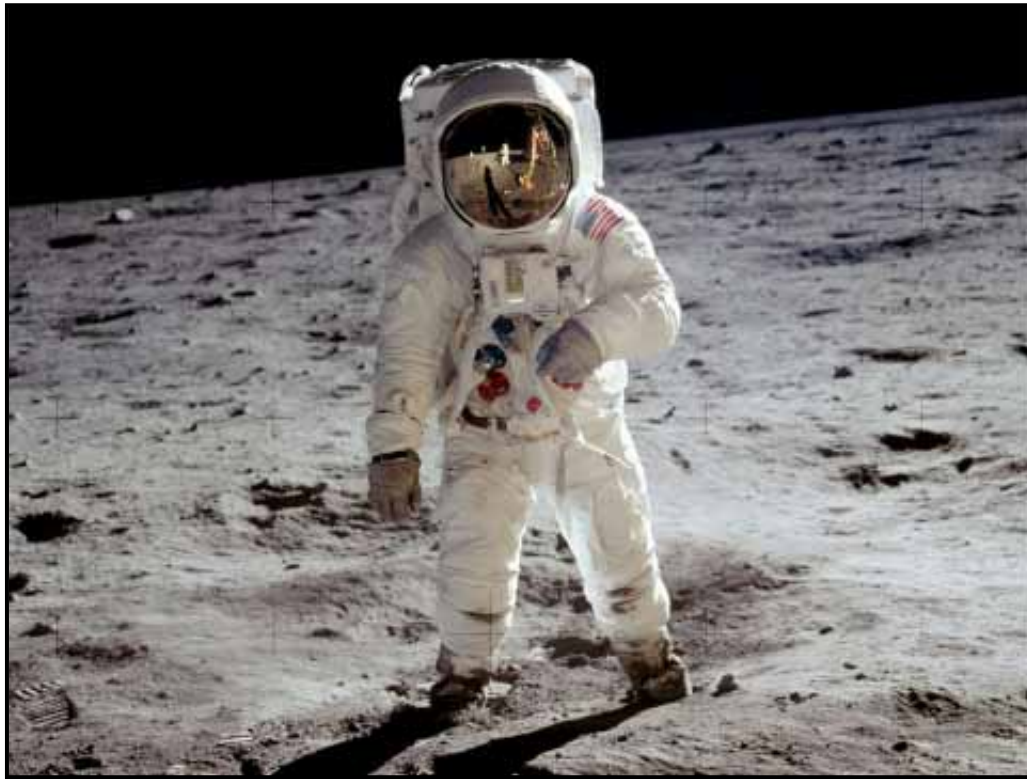
... is that lunar dust is like nothing on Earth, and like nothing that we have toxicology data on.



Image courtesy of Dr. Larry Taylor, University of Tennessee

Lunar Dust is Extremely Abrasive

Lunar dust abrasion effects on joint fittings rendered the Apollo space suits **nearly useless**.



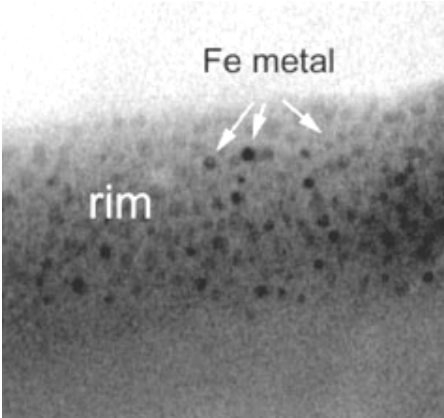
“We must have had more than a hundred hours suited work with the same equipment, and the wear was not so bad on the training suits as it is on these flight suits in just 8 hours we were out. I think it is the abrasiveness of the dust.”

Pete Conrad, Apollo 12
Technical Crew Debriefing,
December 1, 1969.



Lunar Dust—What is it?

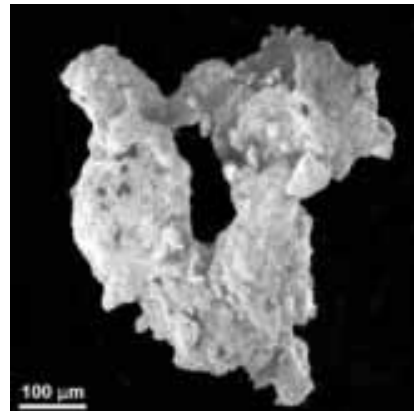
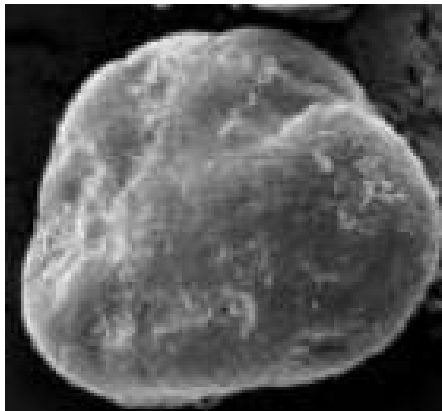
Major Components of Lunar Dust:

SiO_2	~45%
Al_2O_3	~15%
MgO	~10%
CaO	~10%
Fe: a mixture of --FeO --metallic iron ("nanophase iron")	~10%  <p>The micrograph shows a cross-section of a dust particle. A dark, irregularly shaped region is labeled 'Fe metal'. A lighter, more uniform region is labeled 'rim'. Three white arrows point from the 'Fe metal' label to the dark region.</p>



Particle Pulmonary Toxicity

- Crystalline Silica
 - One of the most toxic inhaled substances
 - Triggers inflammation in the lungs (macrophages and epithelial cells)
 - > Acute respiratory compromise?
 - > Fibrosis (scarring): “**Silicosis**”
- Particle size distribution is important ($<3\mu\text{m}$)
- Dust morphology is important (e.g., asbestos)



- **Chemical reactivity is very important!**

Ames Lunar Dust Biological Studies

Lunar Airborne Dust Toxicity
Assessment Group
(LADTAG)

Ames Research
Center

Johnson Space
Center

Areas of concern
relevant to
astronauts

Skin Studies

Ocular Studies

Cell Studies to
support JSC
Pulmonary
Toxicity

Pulmonary
Toxicity

Immune
Sensitization
Effects

Irritant Effects

Abrasion Effects





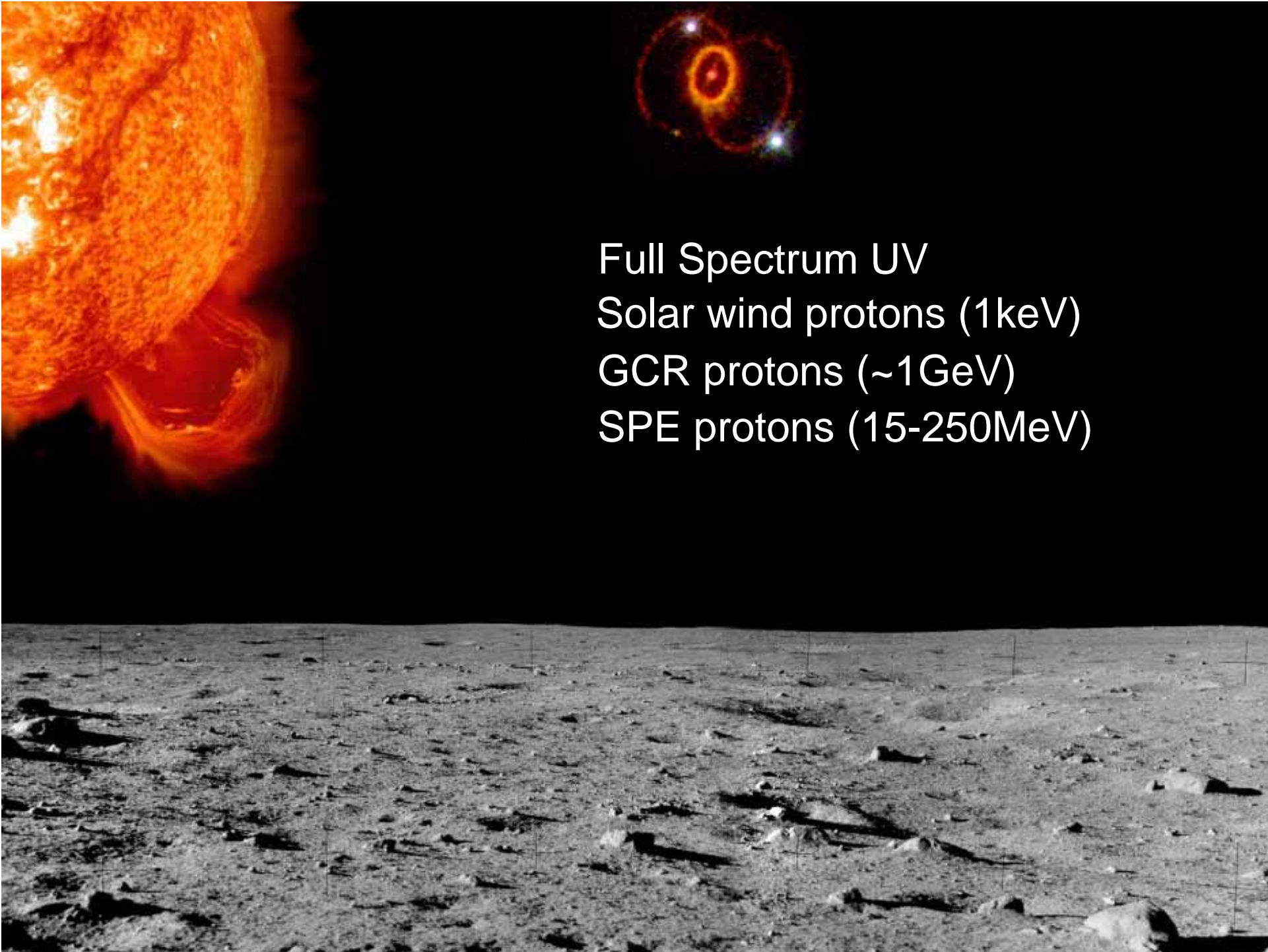
What Does “Chemical Reactivity” Mean?

“Chemical Reactivity” means surface radicals that can interact with oxygen and water.

Potential sources of surface radicals on lunar dust:

- Mechanical effects — grinding, and breaking
- Radiation effects —

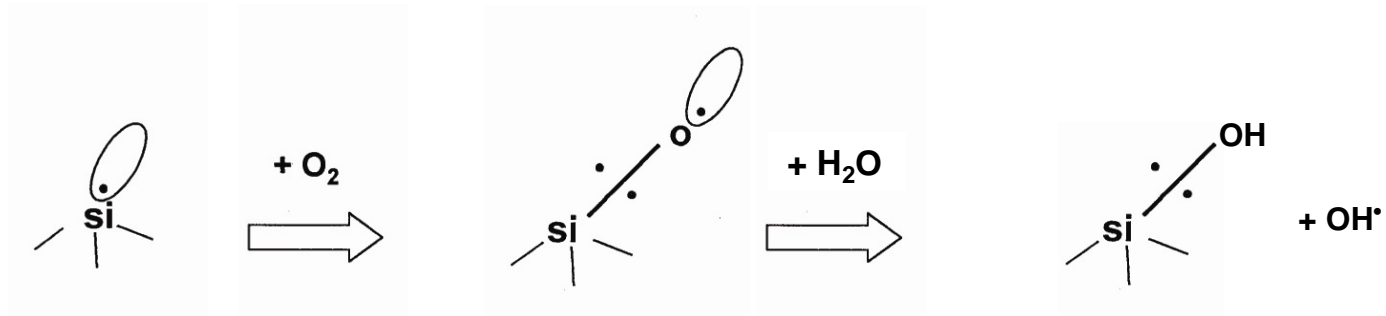




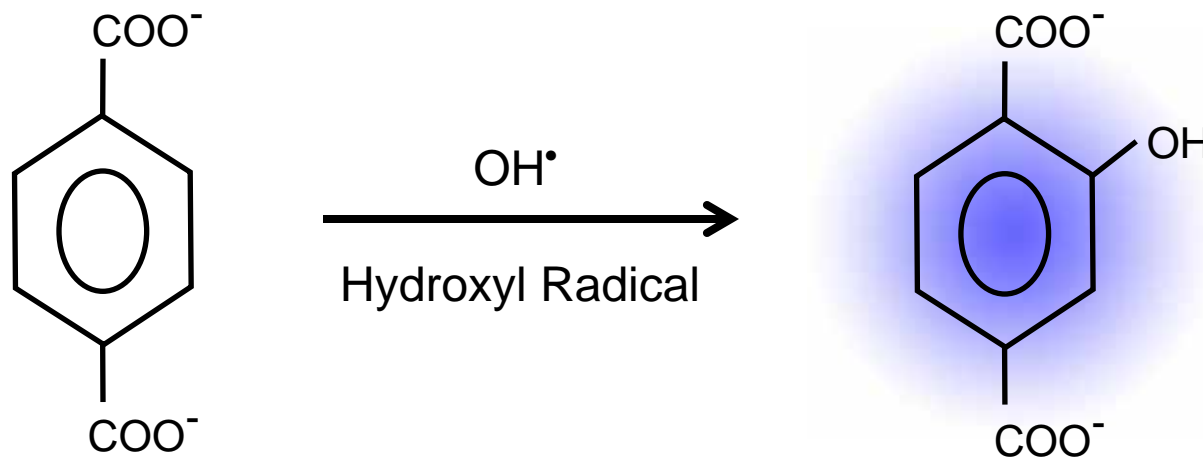
Full Spectrum UV
Solar wind protons (1keV)
GCR protons (~1GeV)
SPE protons (15-250MeV)

Hydroxyl Radical Generation on Mineral Surfaces

Adapted from Fubini 2003



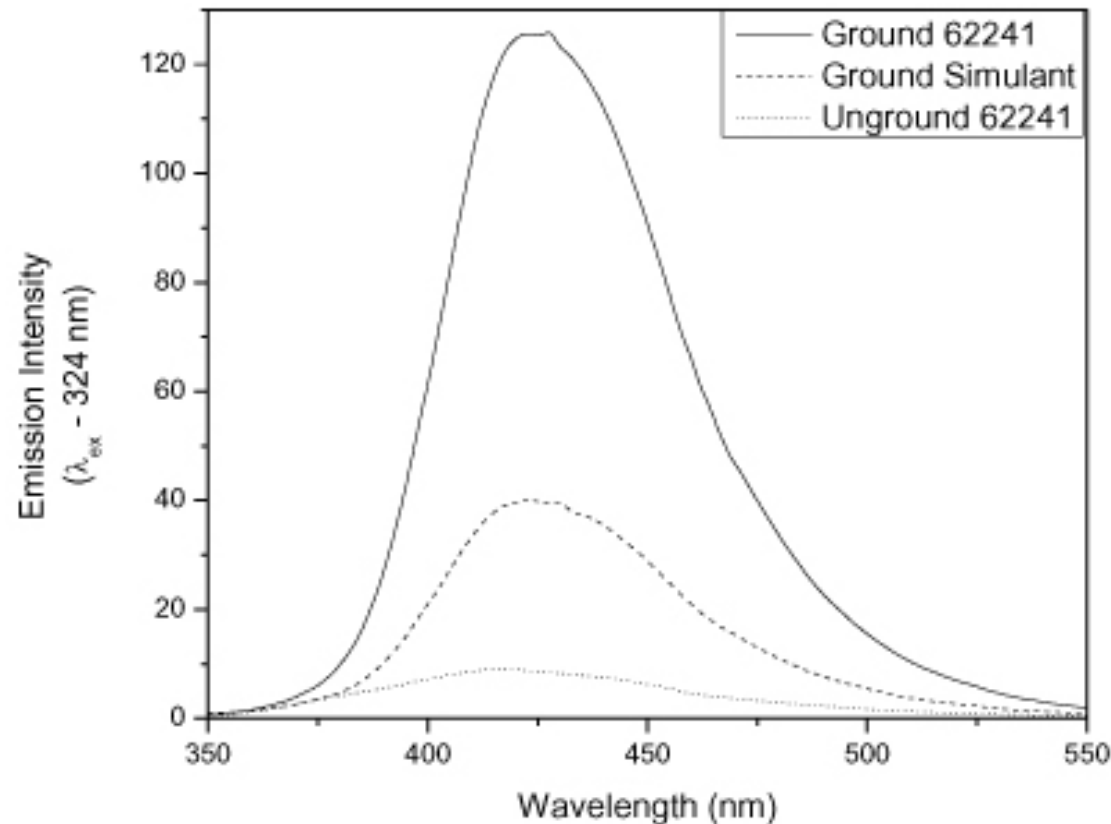
So the question becomes how do we measure OH^\bullet ?



Excitation at 325 nm; Emission at 425 nm

Terephthalate Assay Results

Results of Dr.
Billy Wallace
at NASA JSC



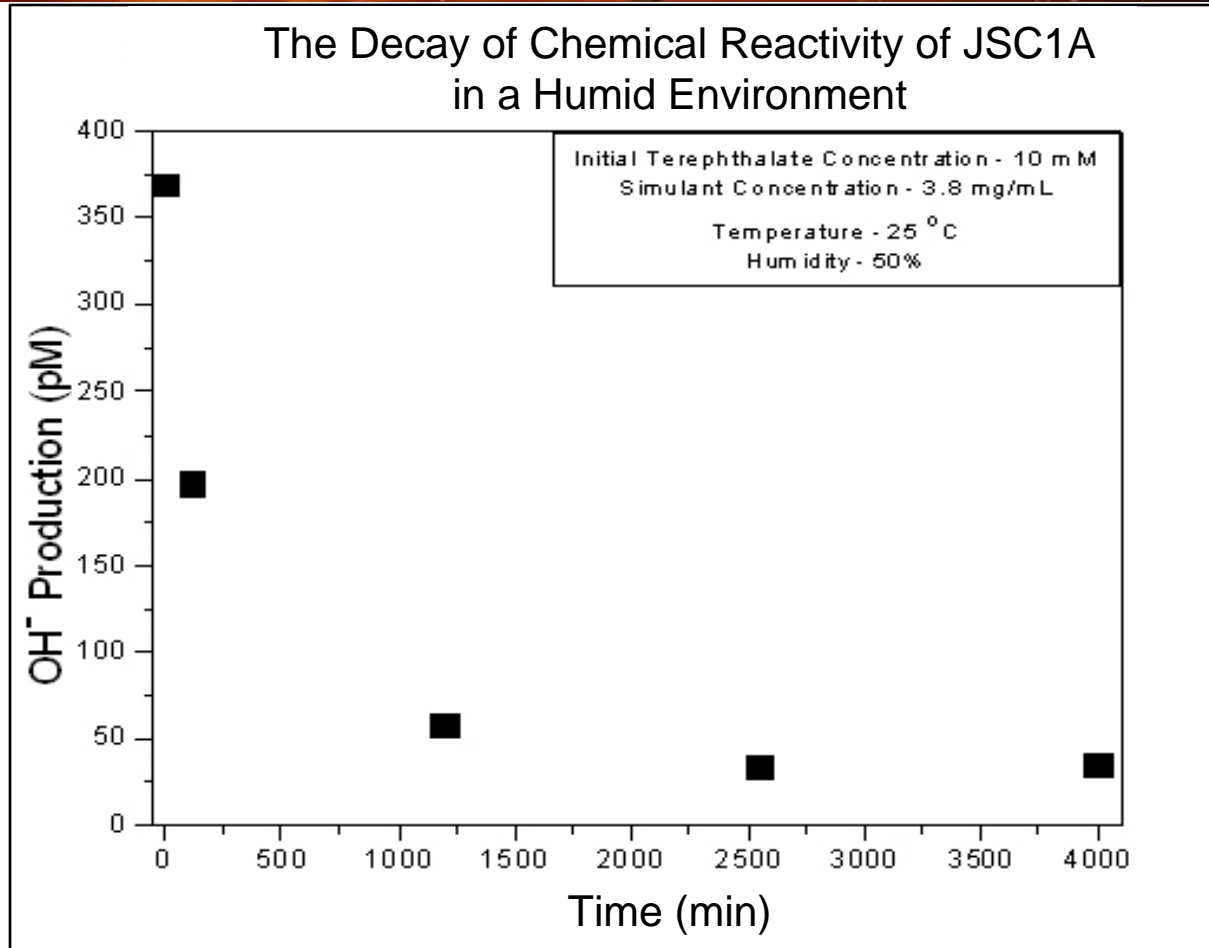
- As for terrestrial silica, grinding is a potent mechanism for activation of lunar dust.



- The effect is much more pronounced for actual lunar dust, compared to simulant (JSC1a).

Terephthalate Assay Results

Results of Dr.
Billy Wallace
at NASA JSC



- The chemical reactivity of lunar dust decays over a time course of minutes in a humid environment (similar to silica).



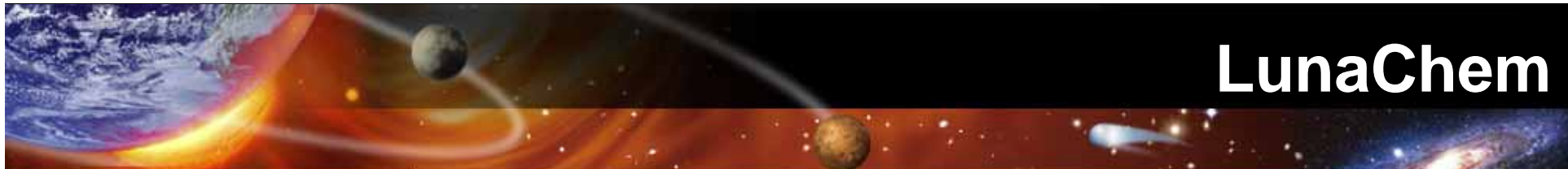
What is the decay curve for radiation
induced chemical reactivity?



So Then Why LunaChem?

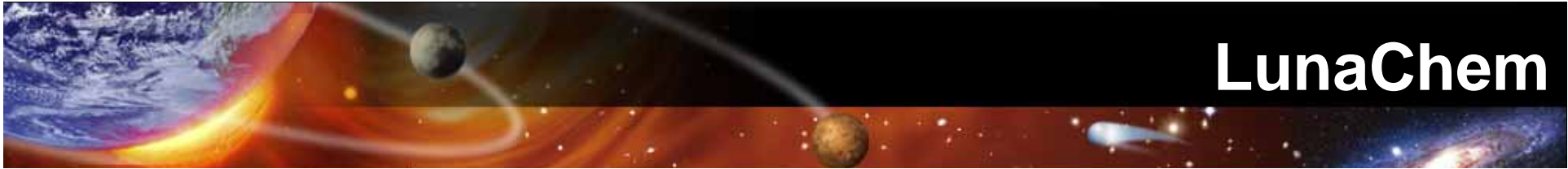
- When the Apollo Lunar Dust was returned from the Moon the chemical reactivity of it was never studied.
- Chemical reactivity decay has had likely decayed over time. Today, there is little left of that initial chemical reactivity.
 - Earth based experiments are working to understand the process of radiation induced activation, however we will never know the true extent of chemical activation on the Moon.



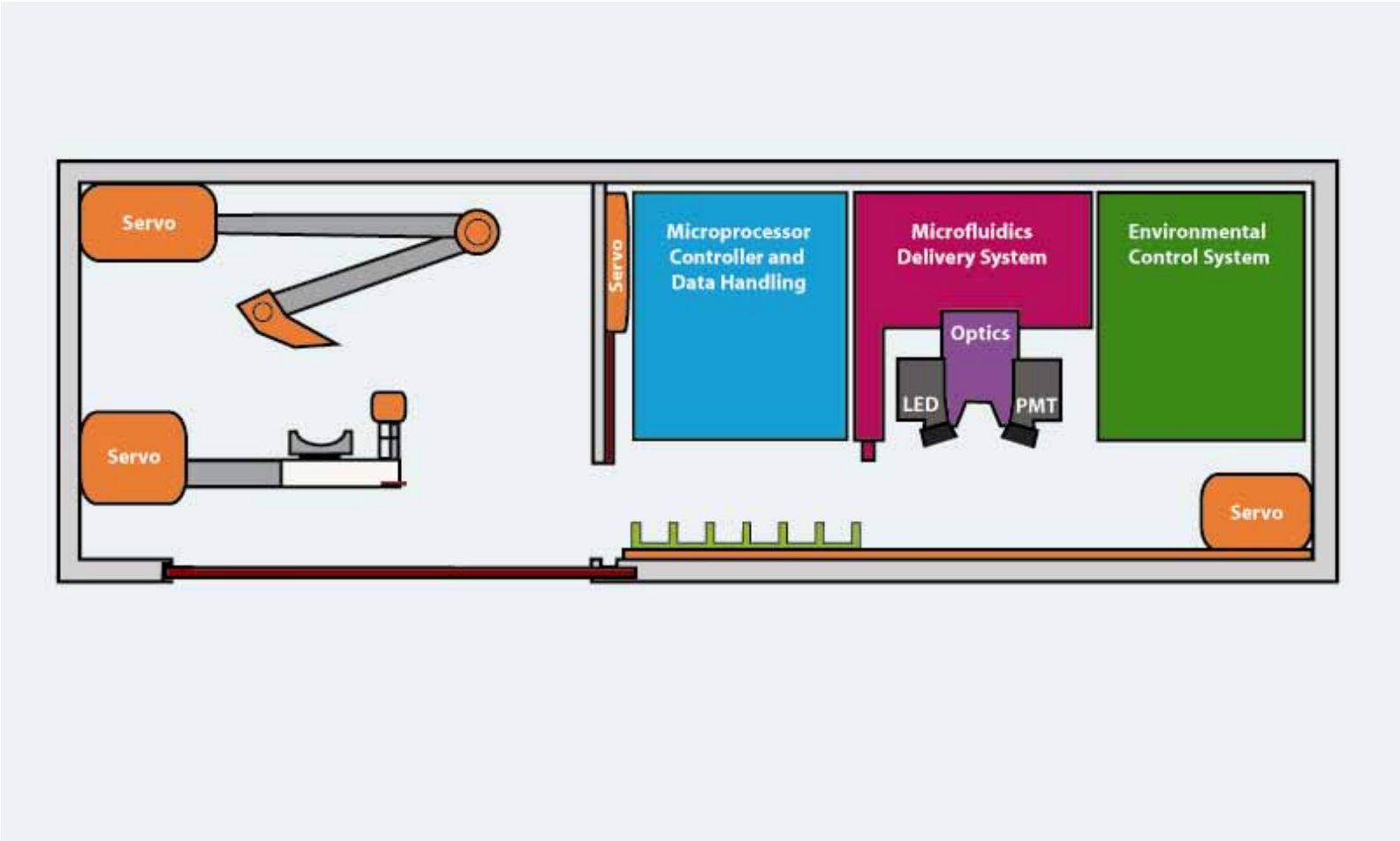


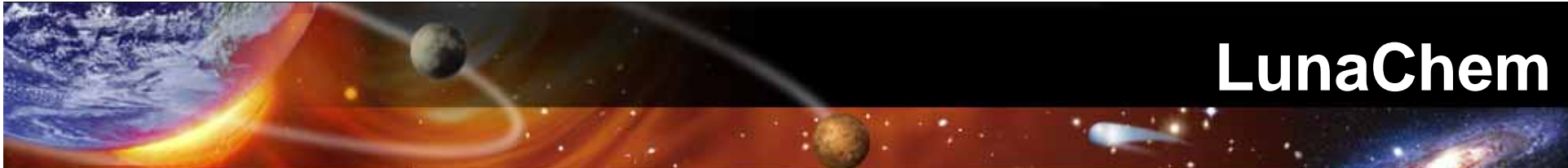
An instrument for determining the chemical reactivity
of lunar dust *in situ*



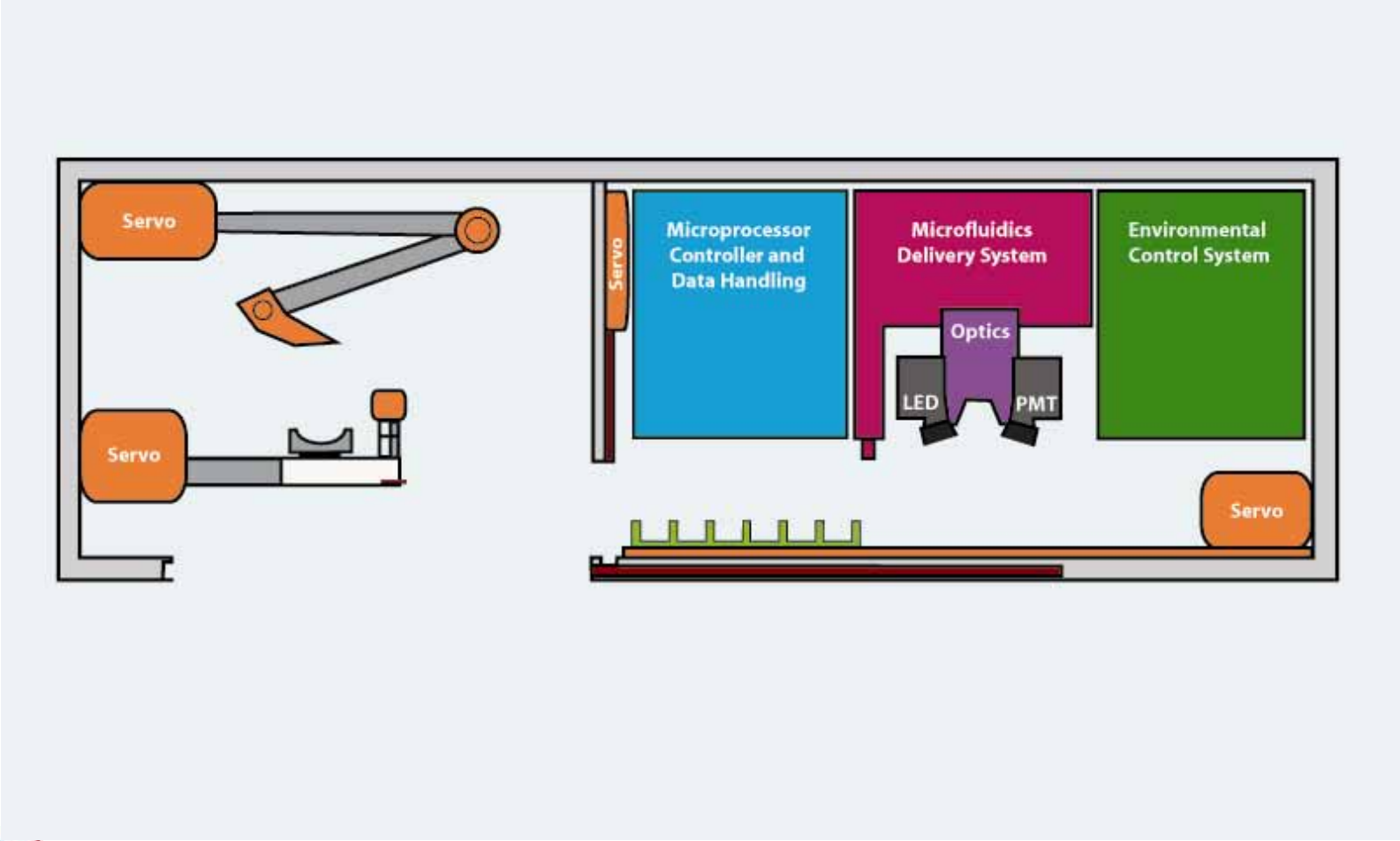


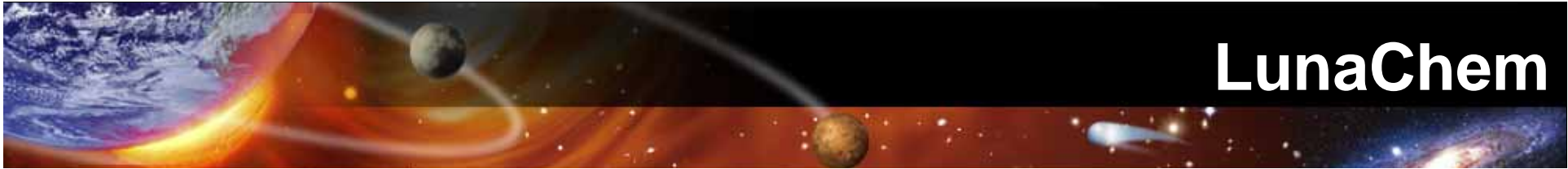
LunaChem



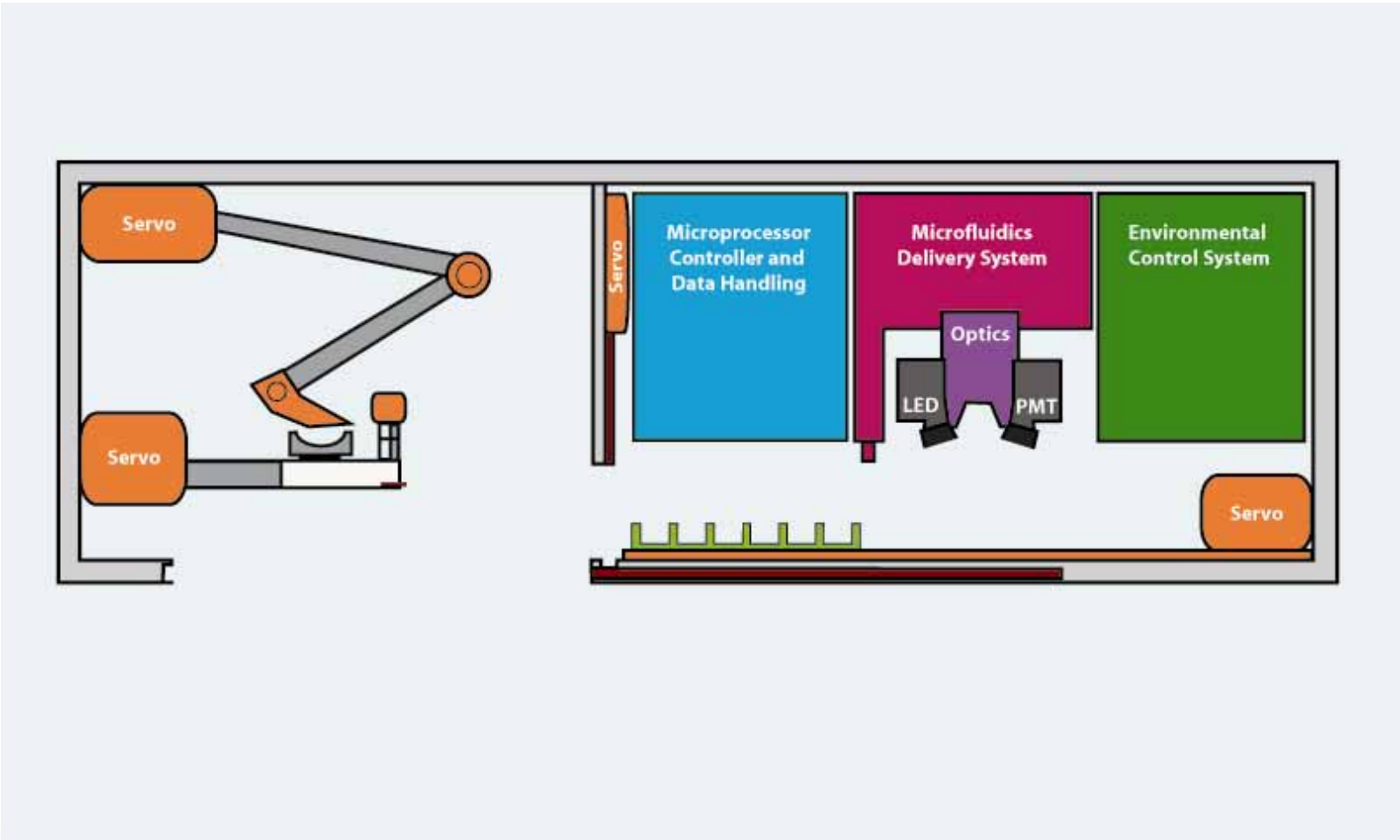


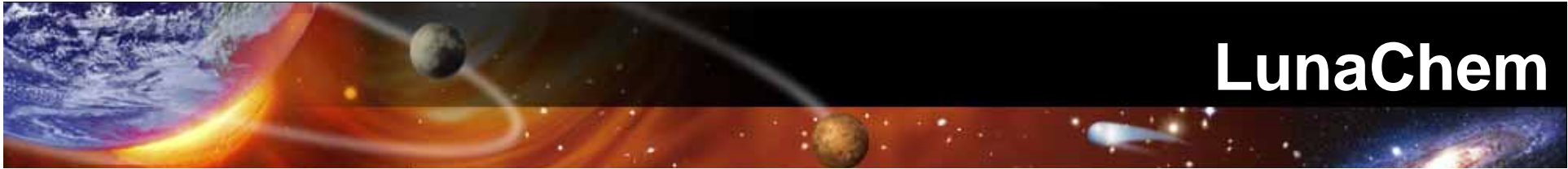
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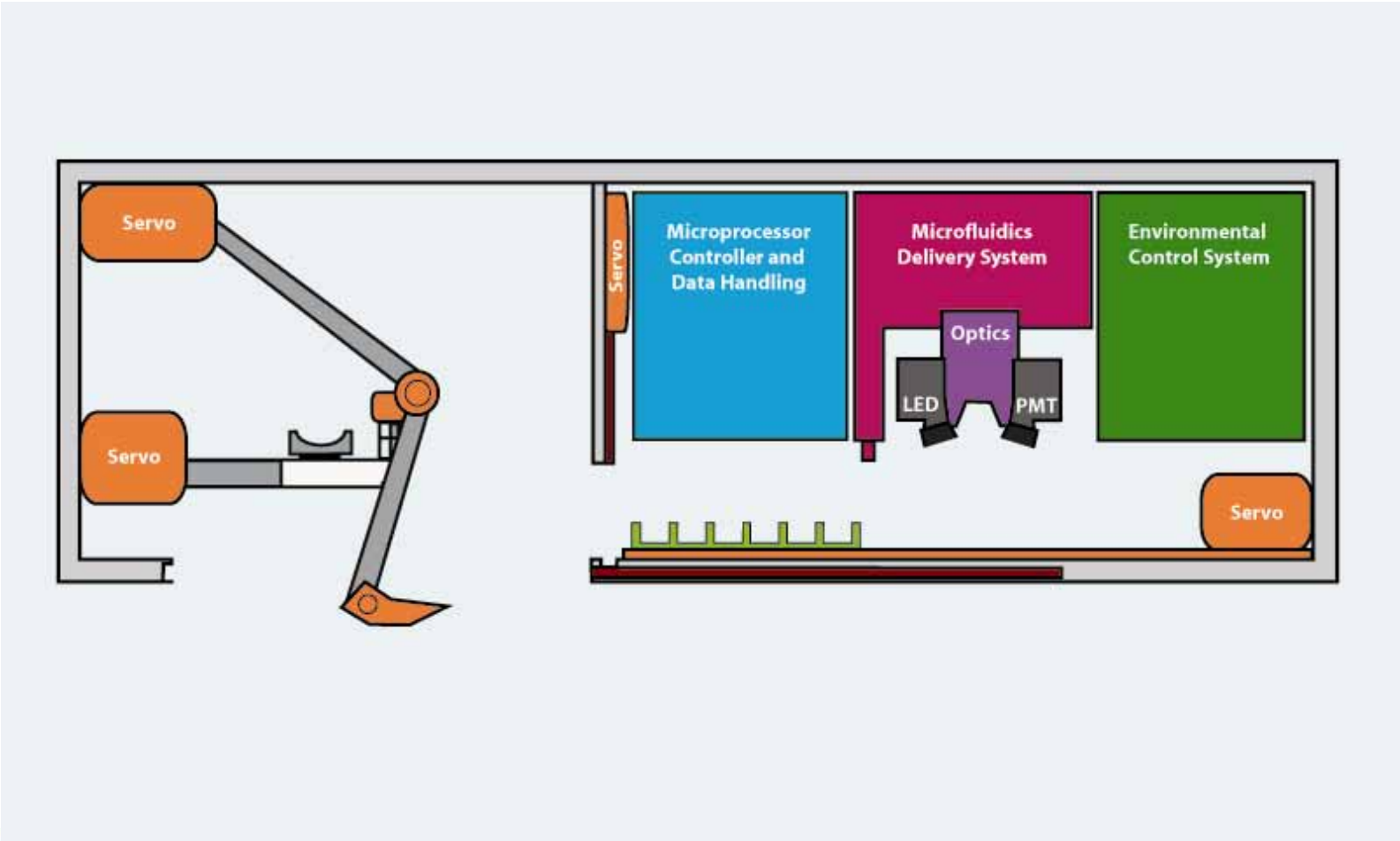


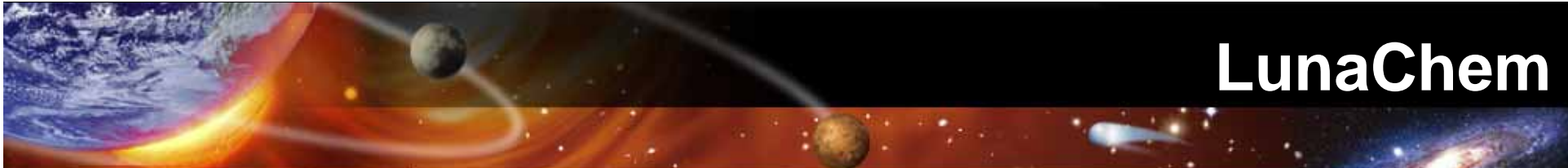
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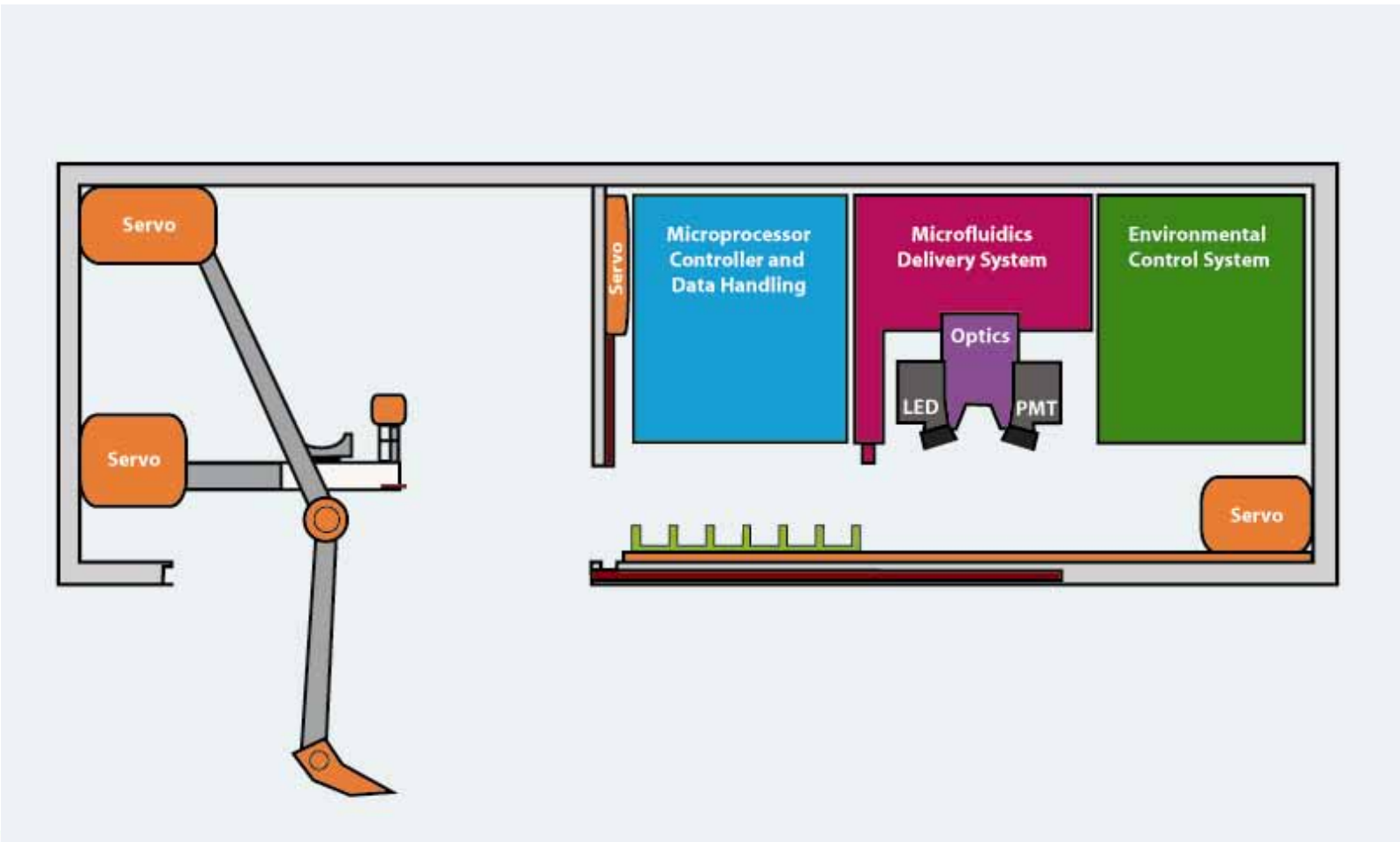


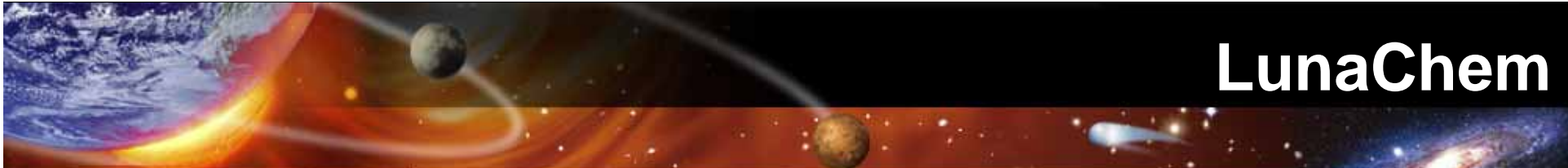
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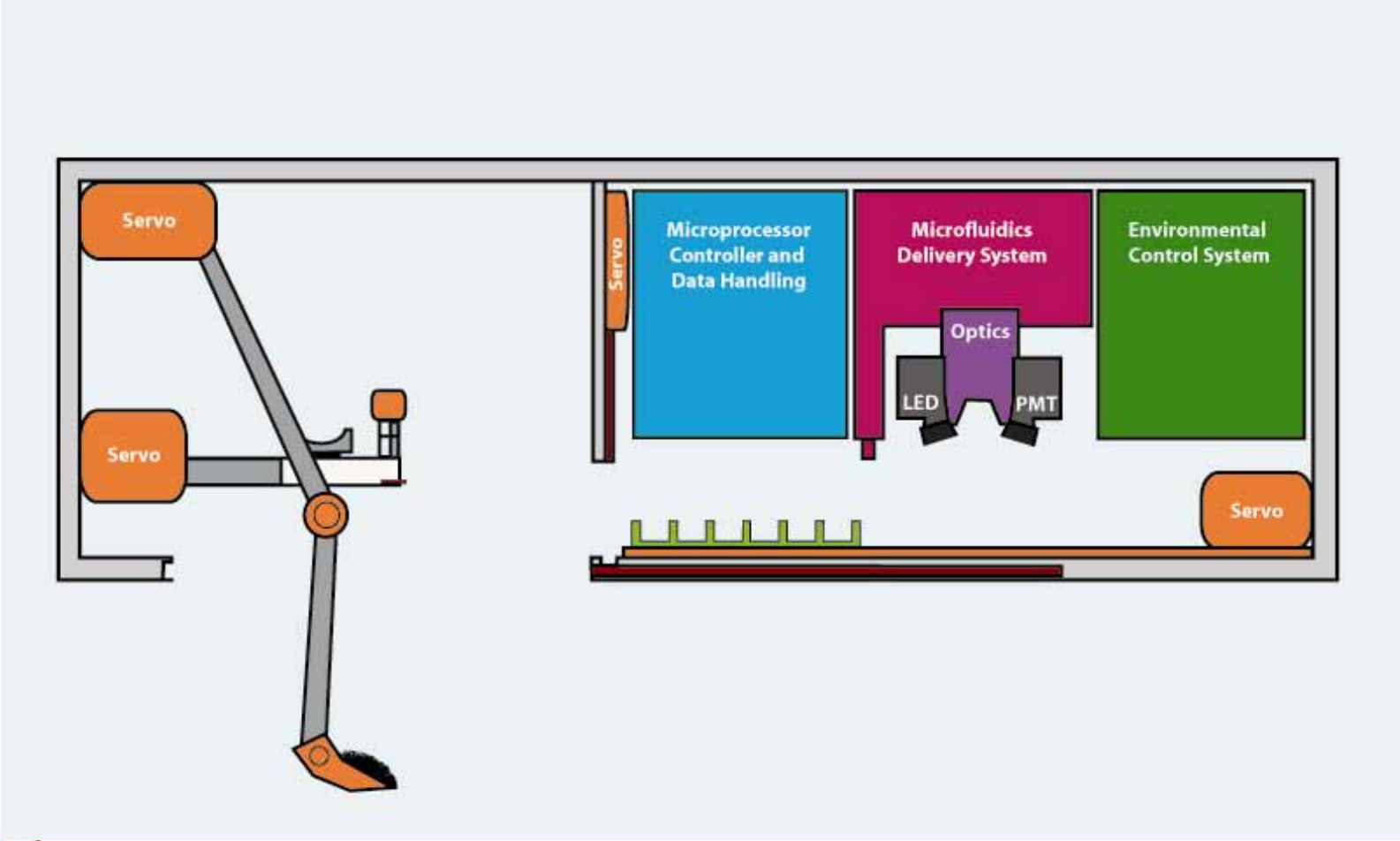


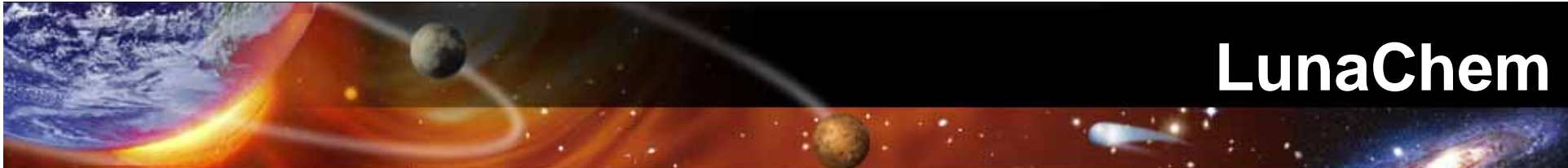
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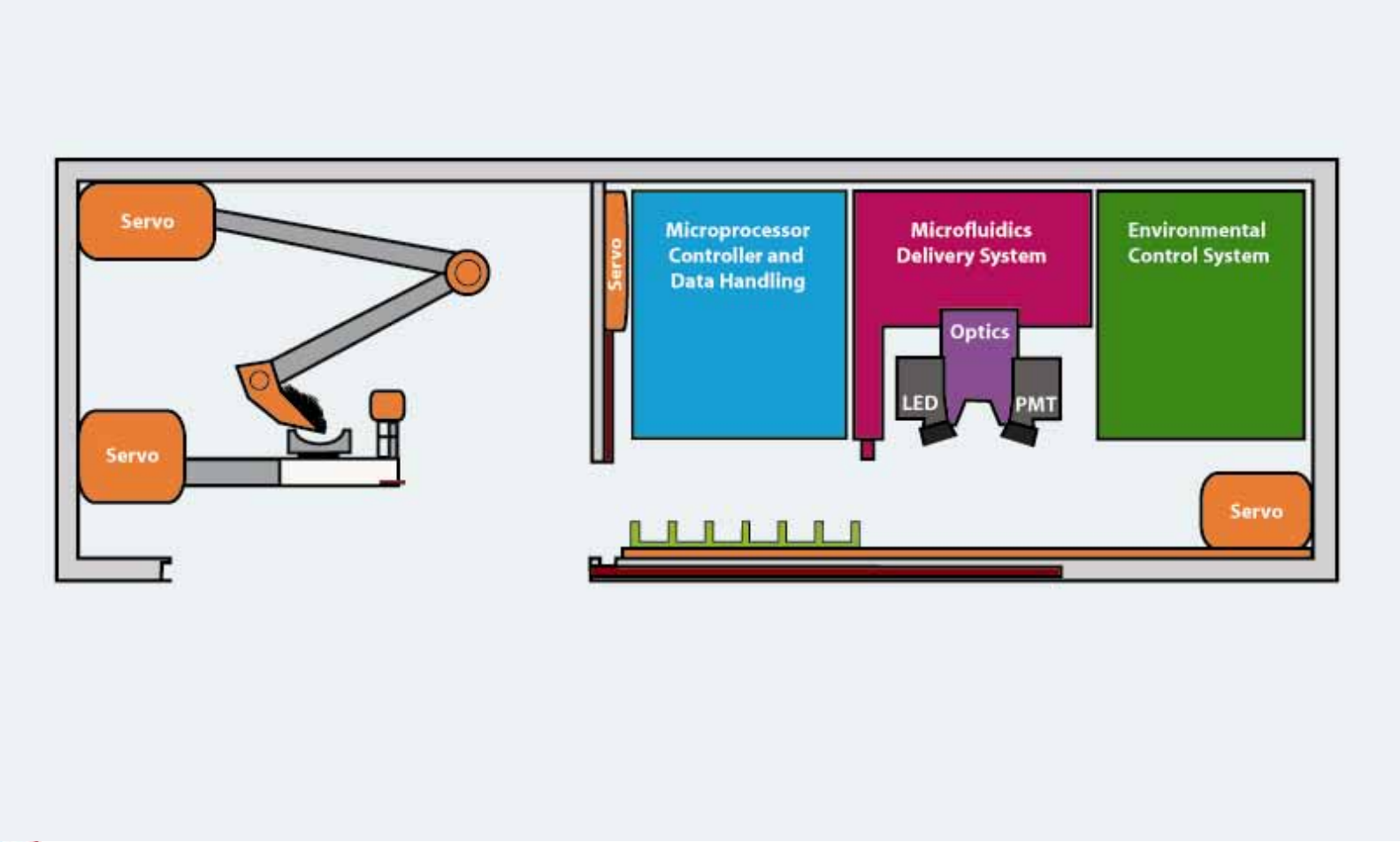


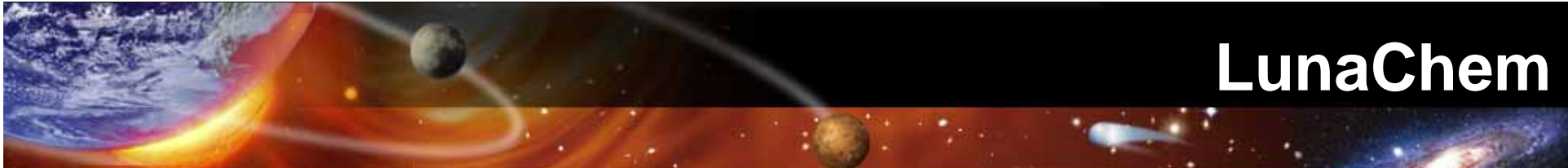
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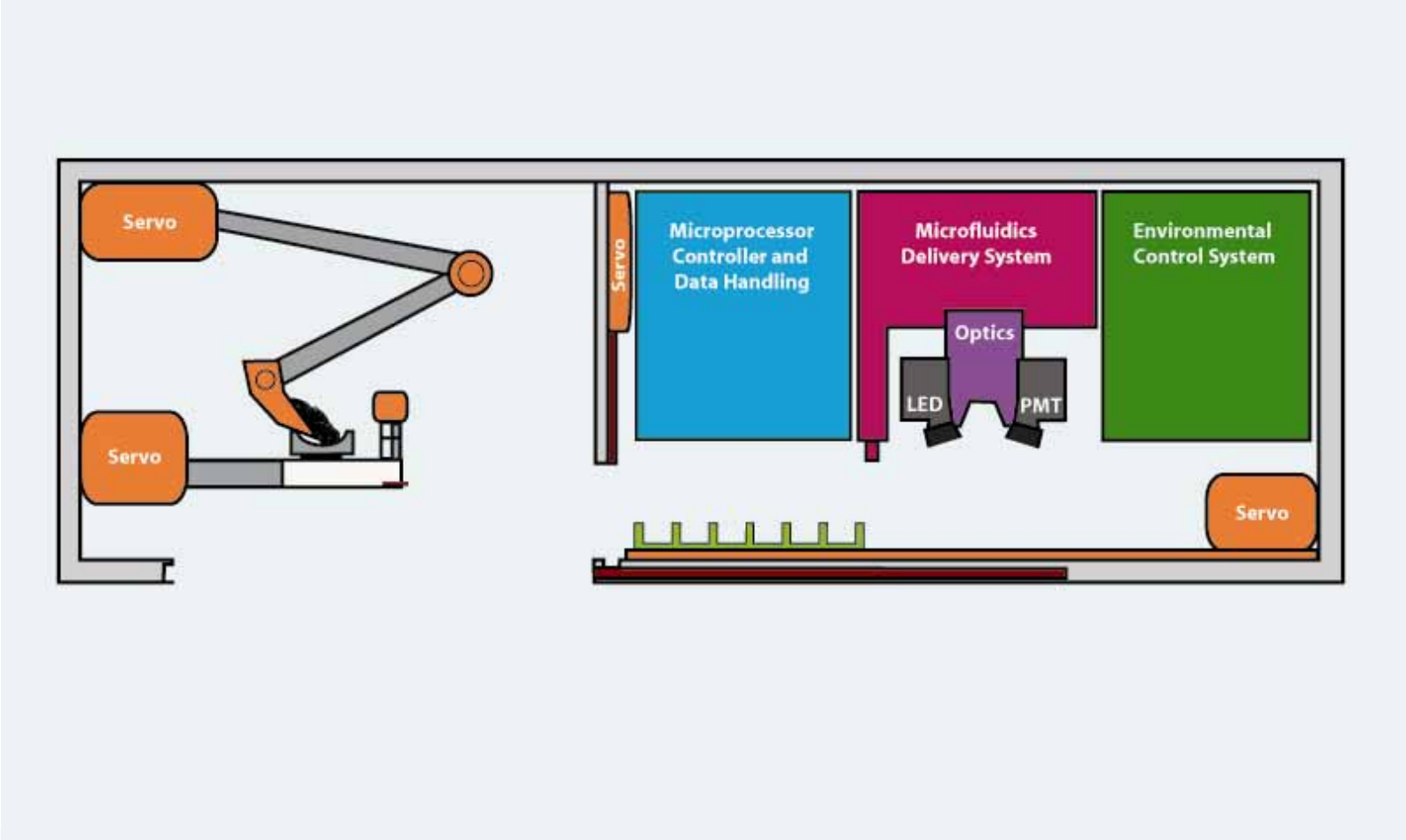


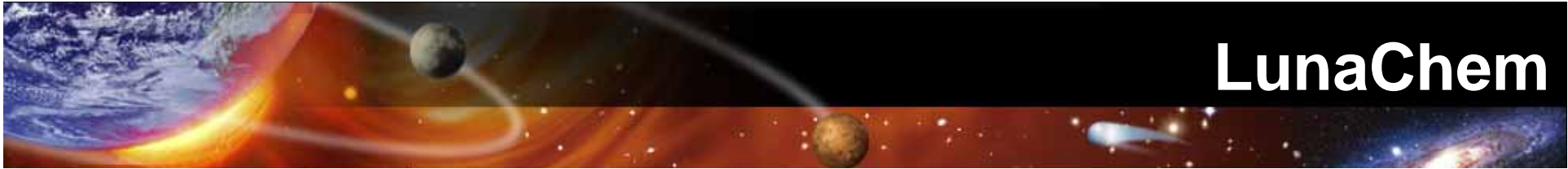
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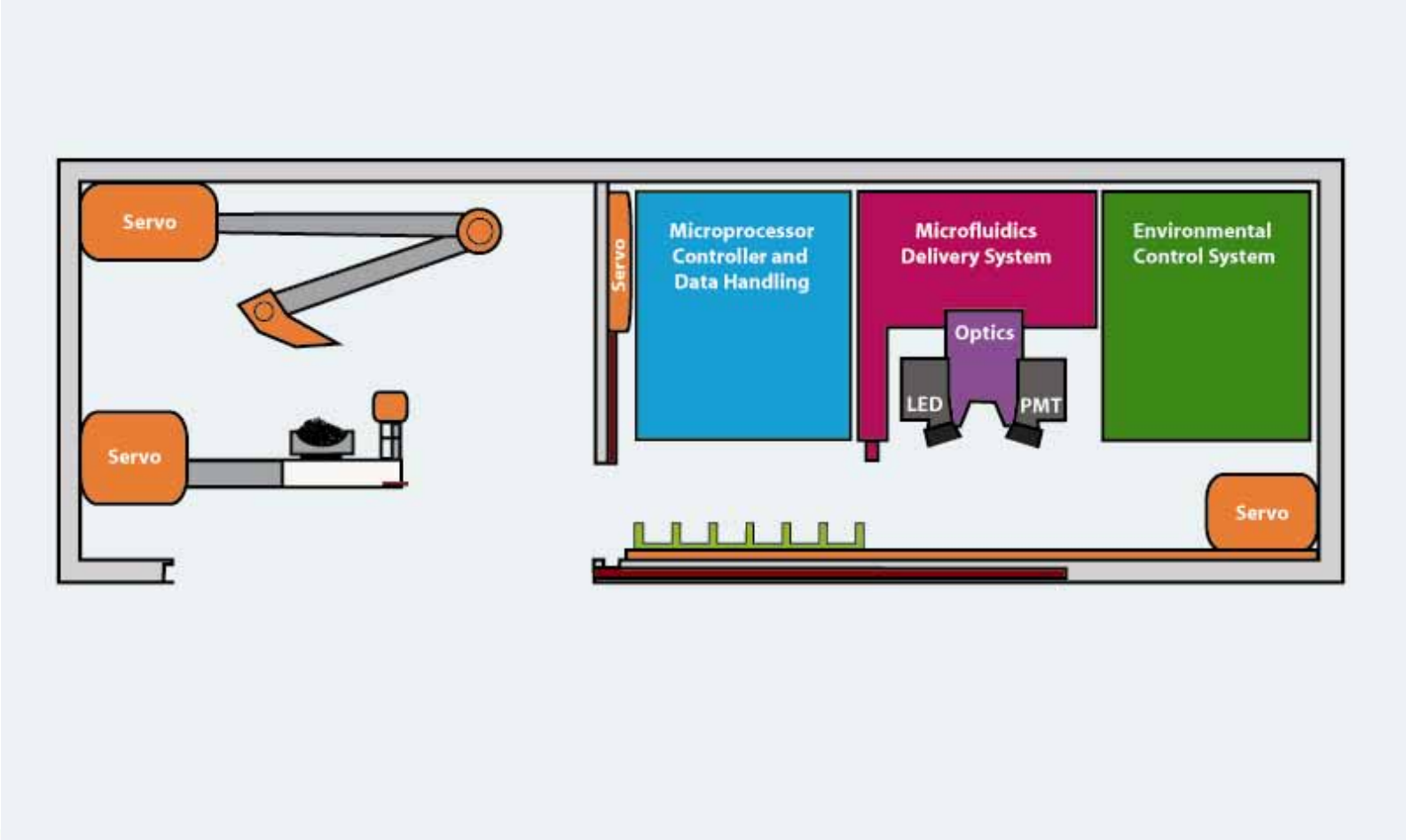


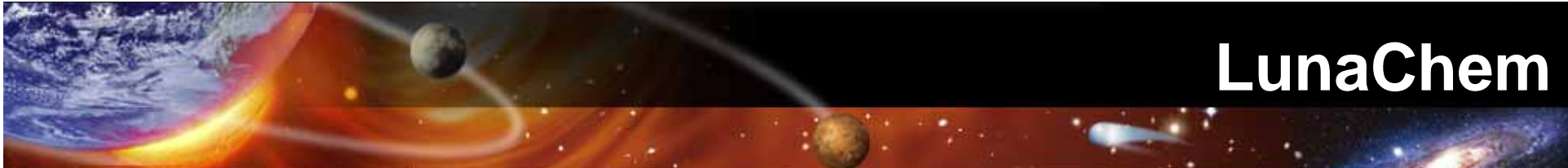
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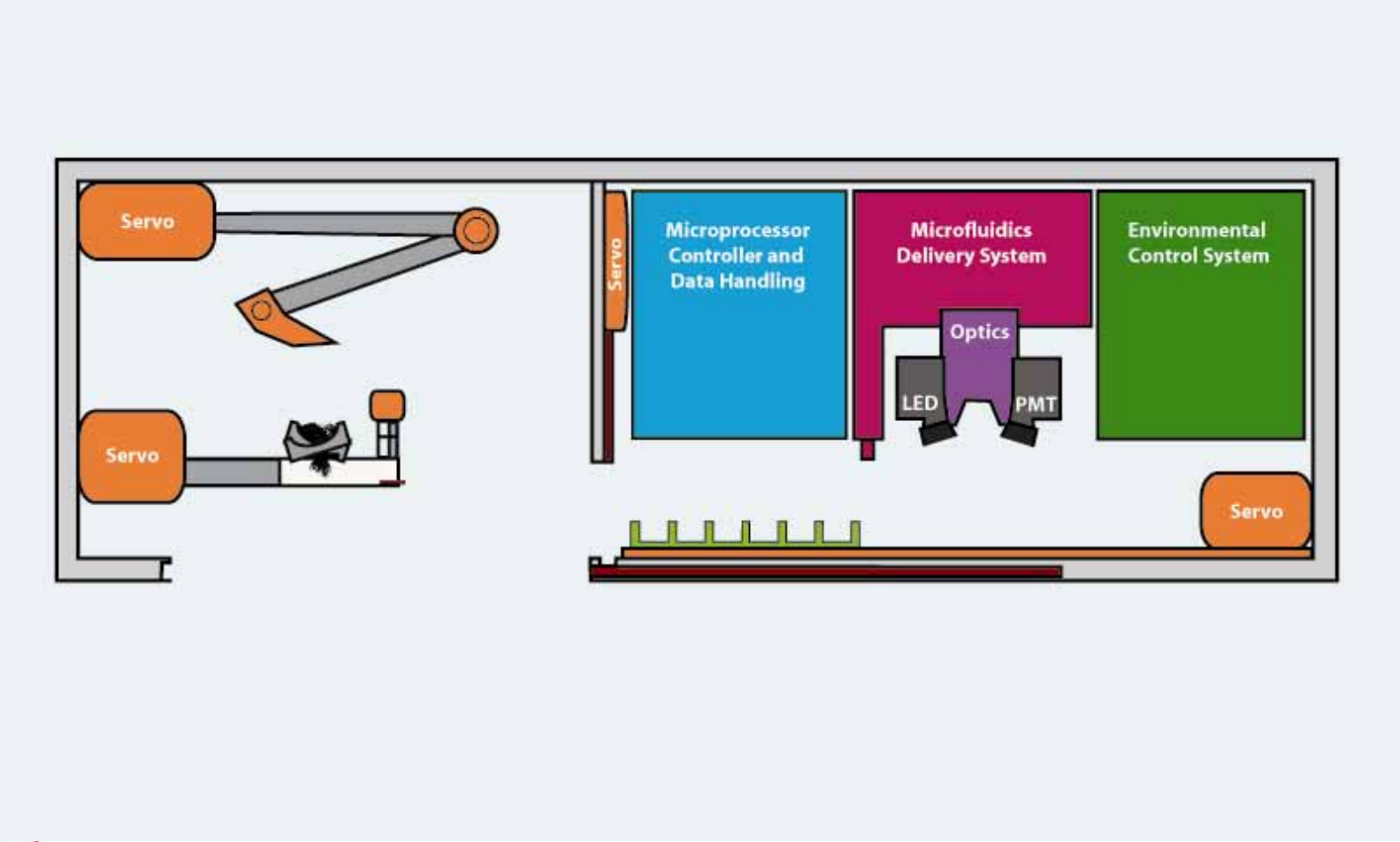


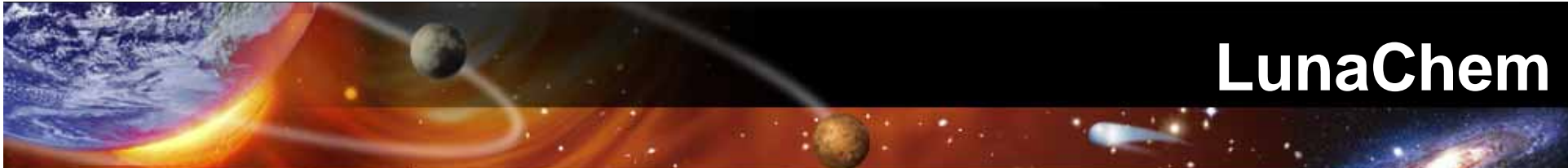
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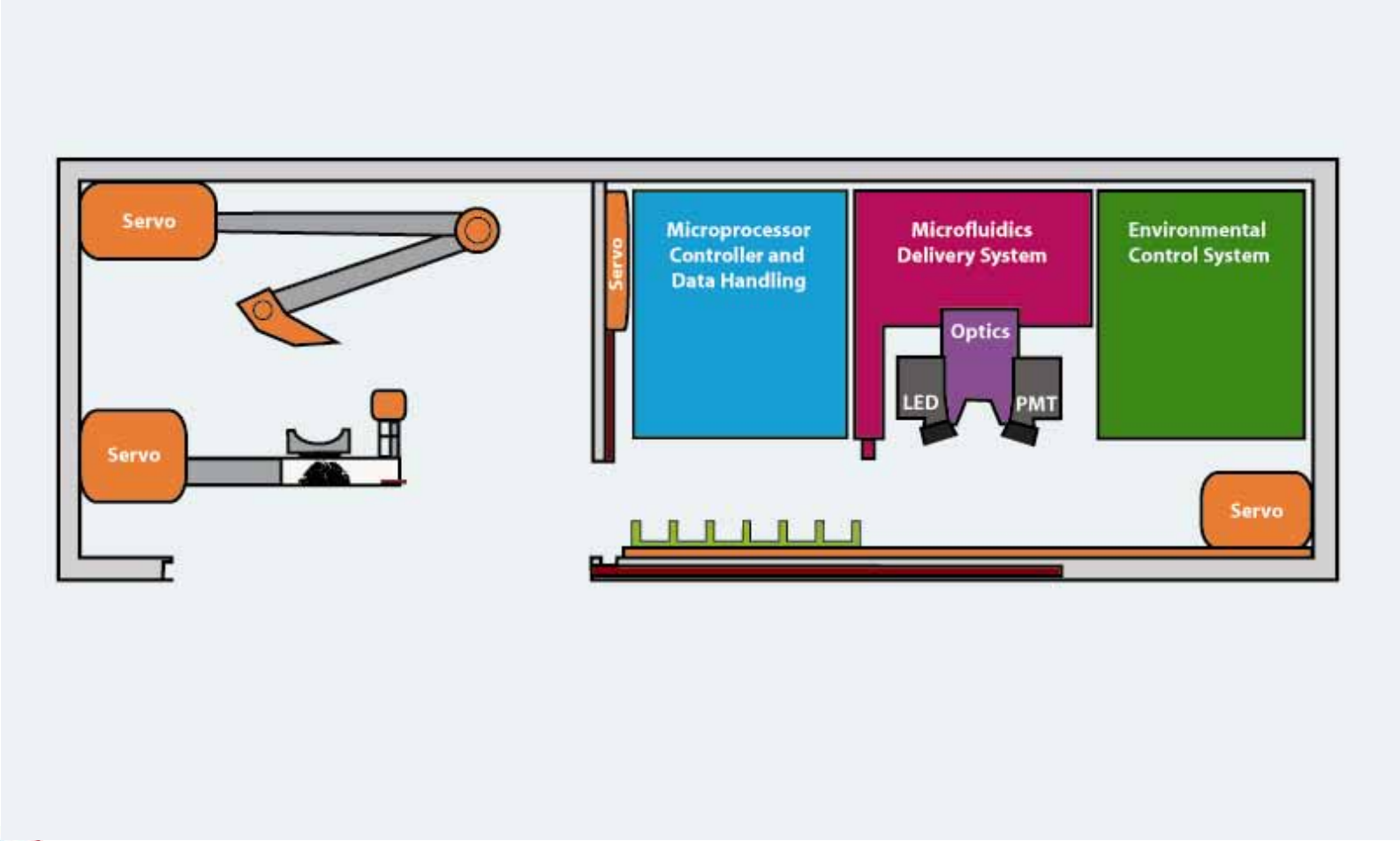


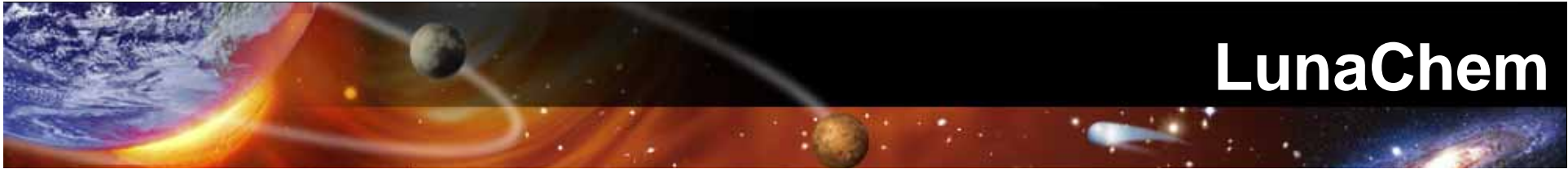
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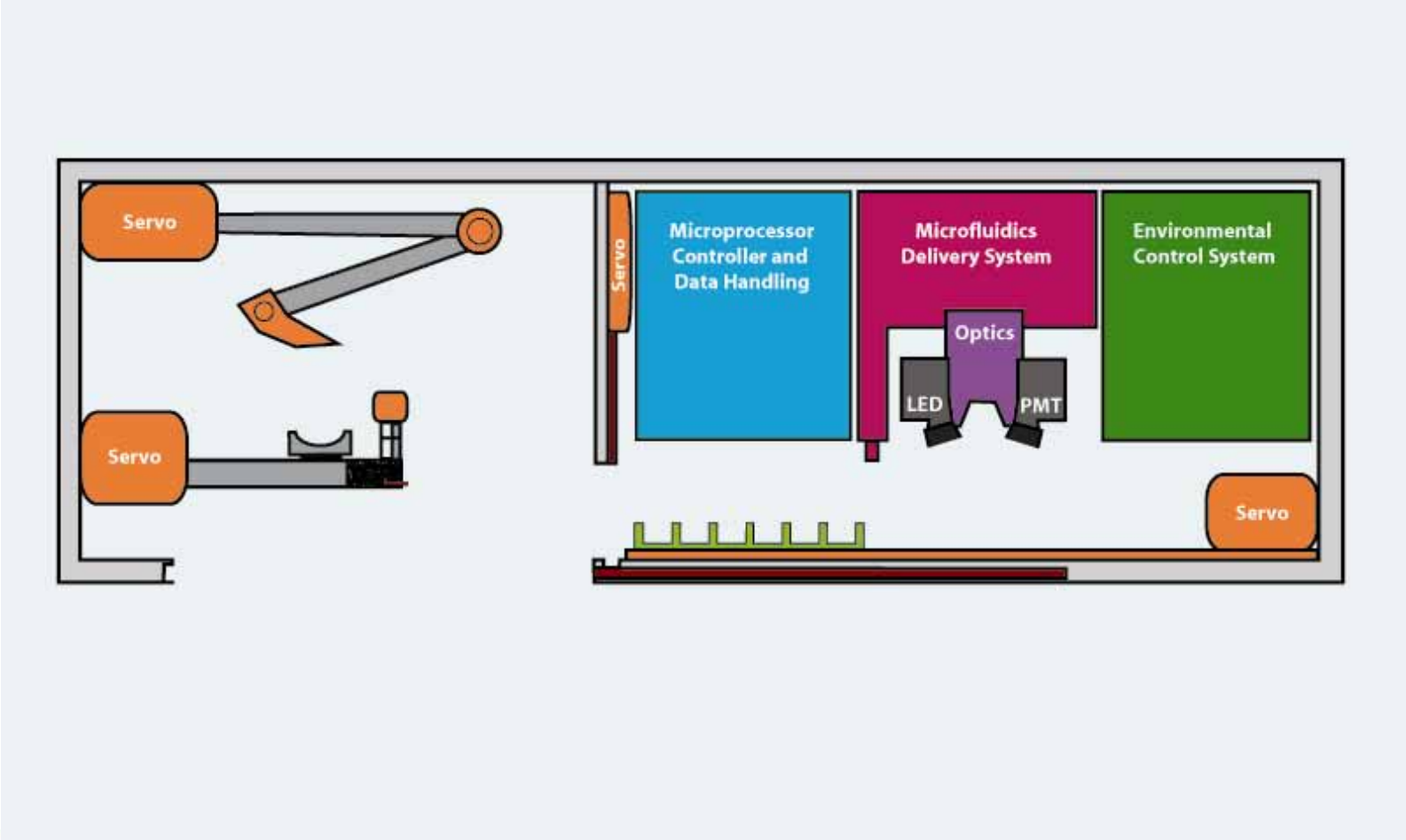


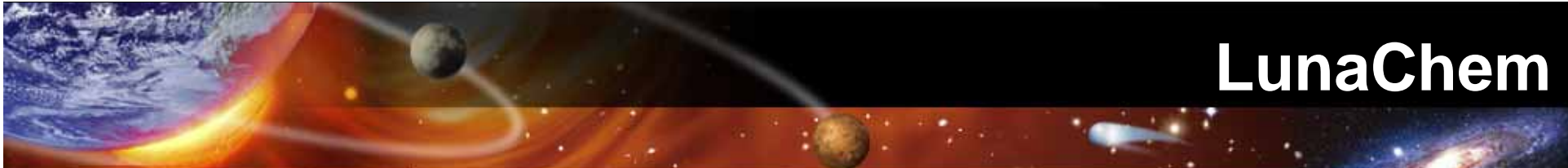
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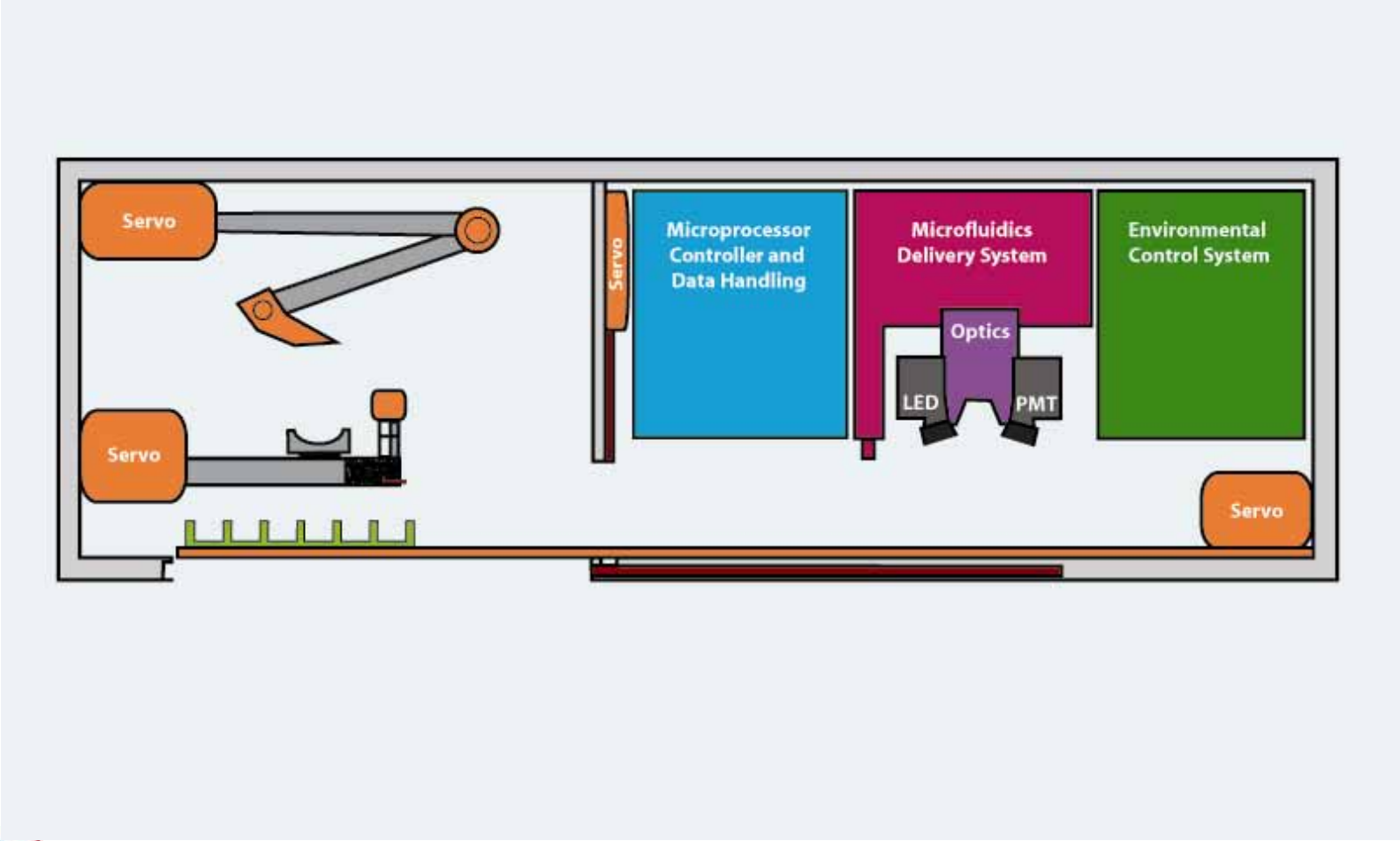


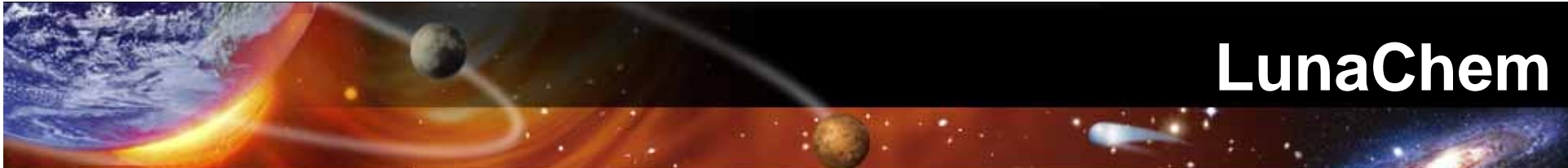
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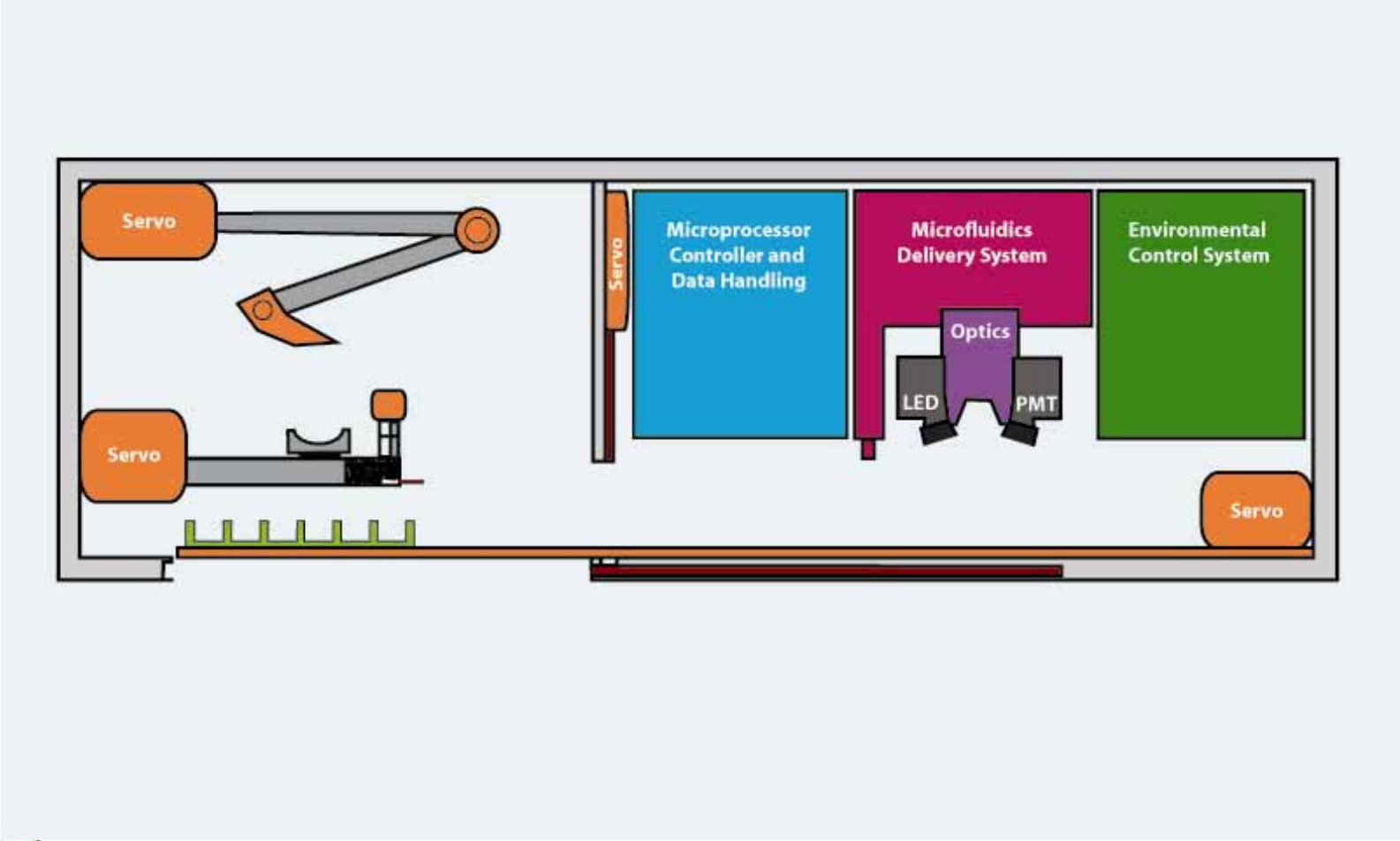


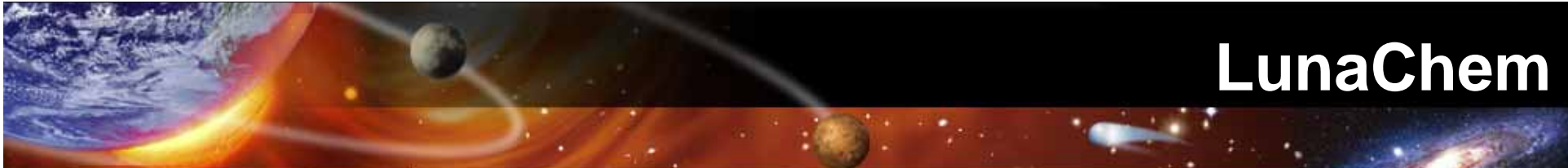
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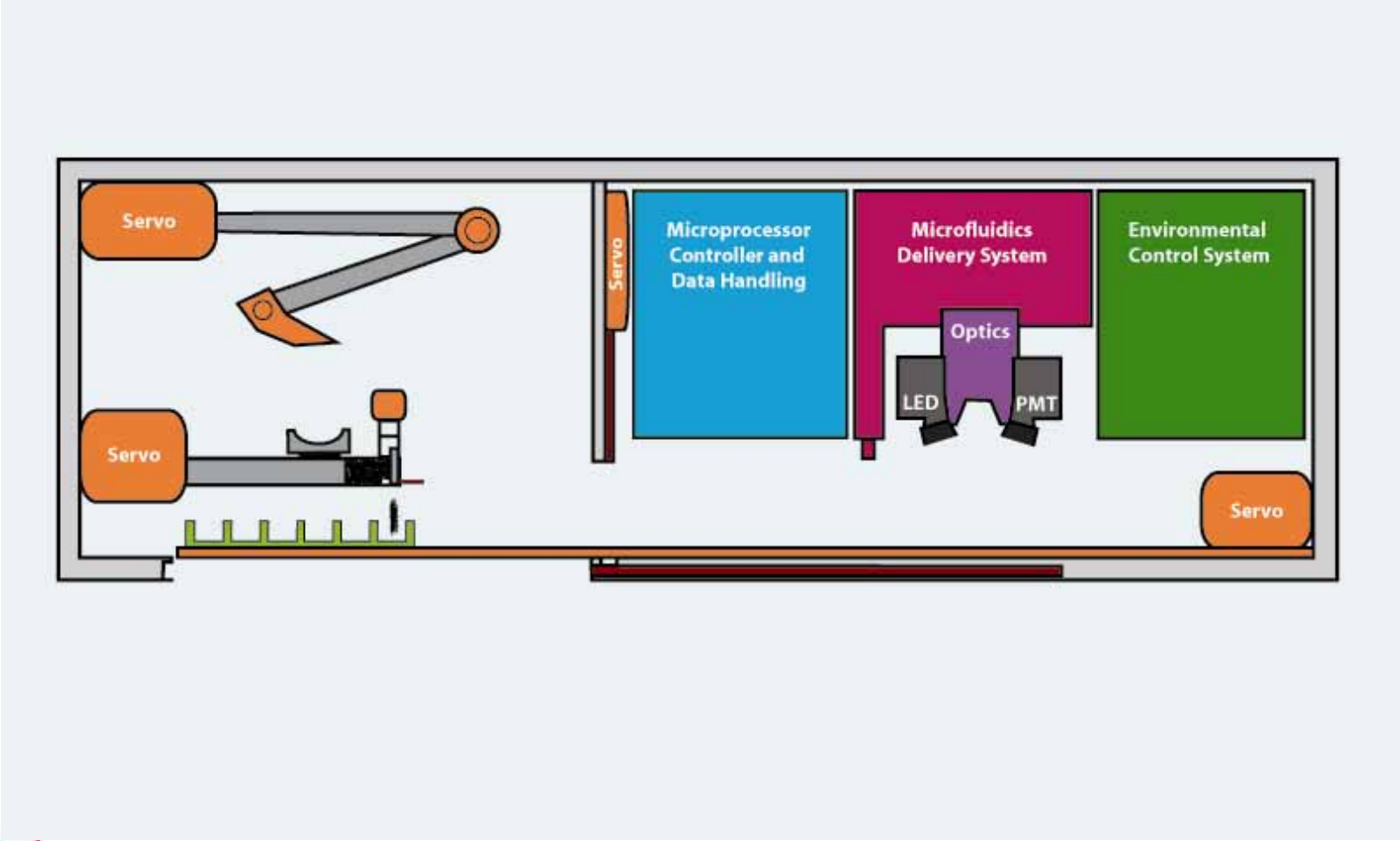


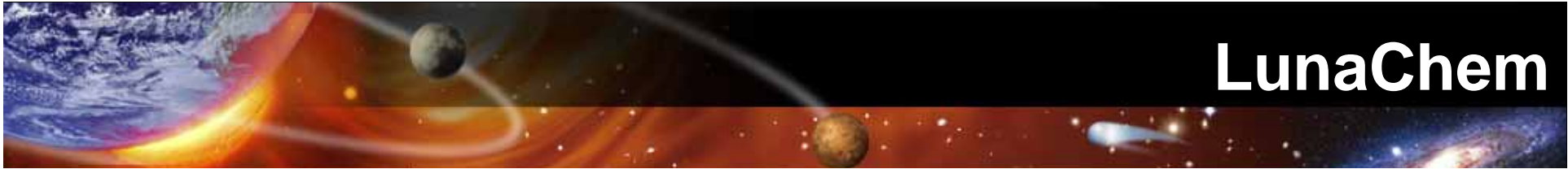
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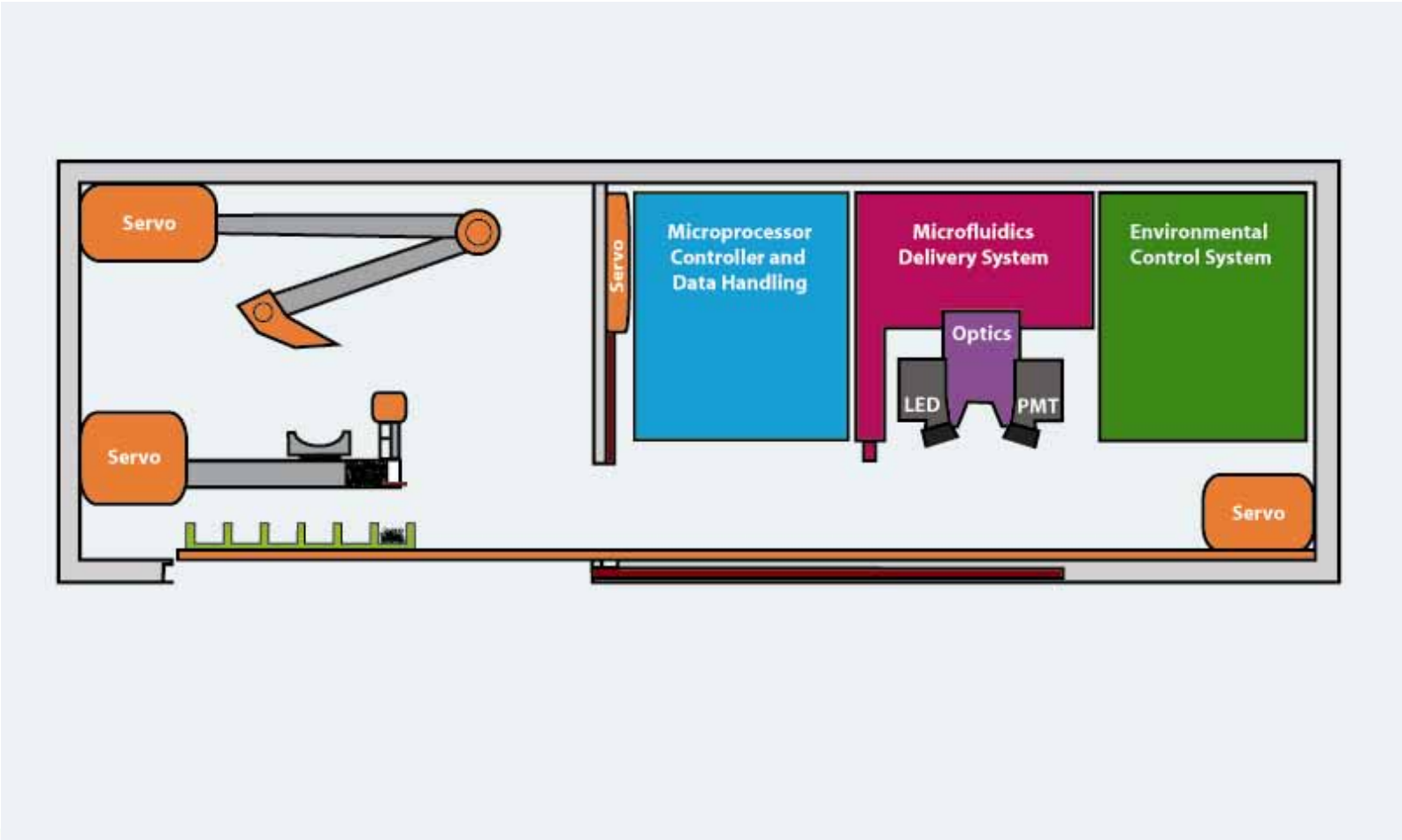


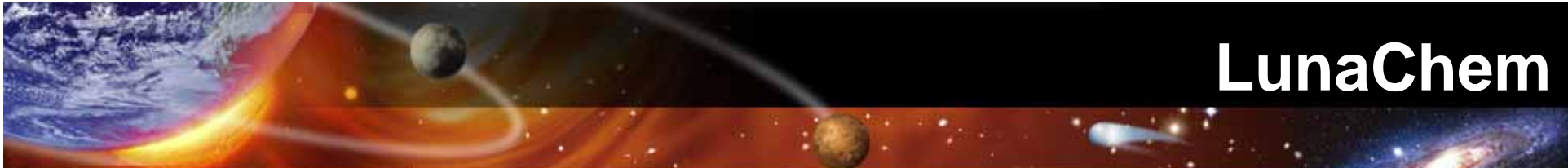
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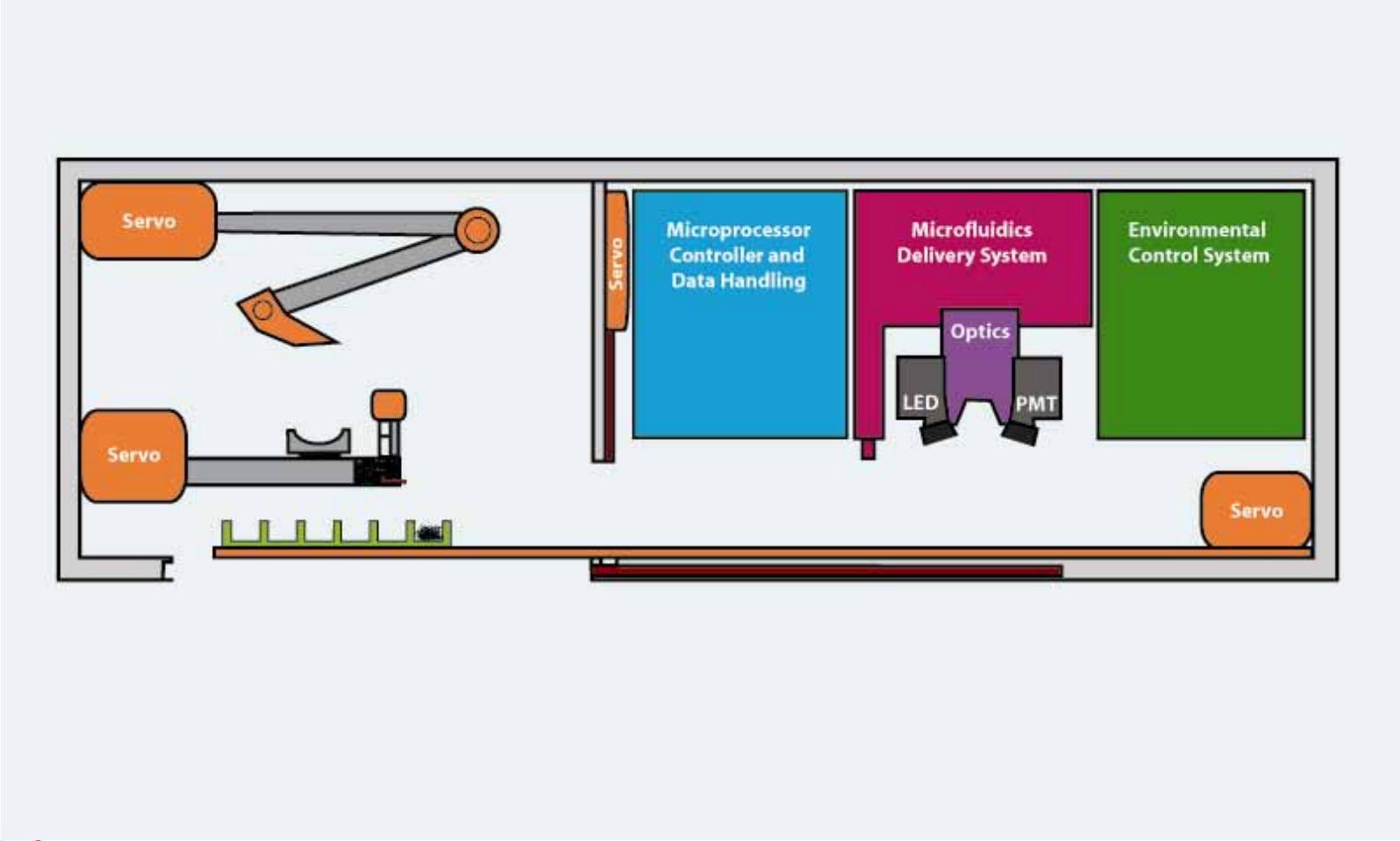


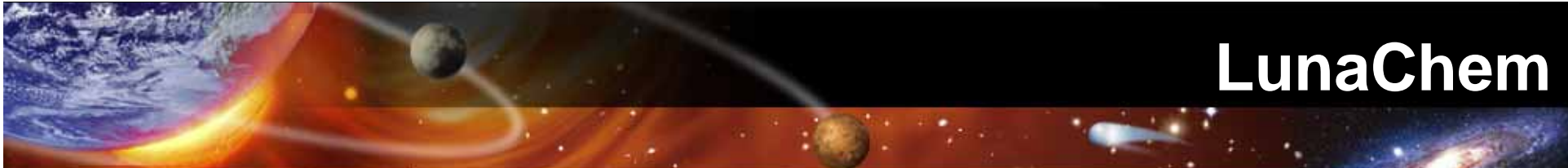
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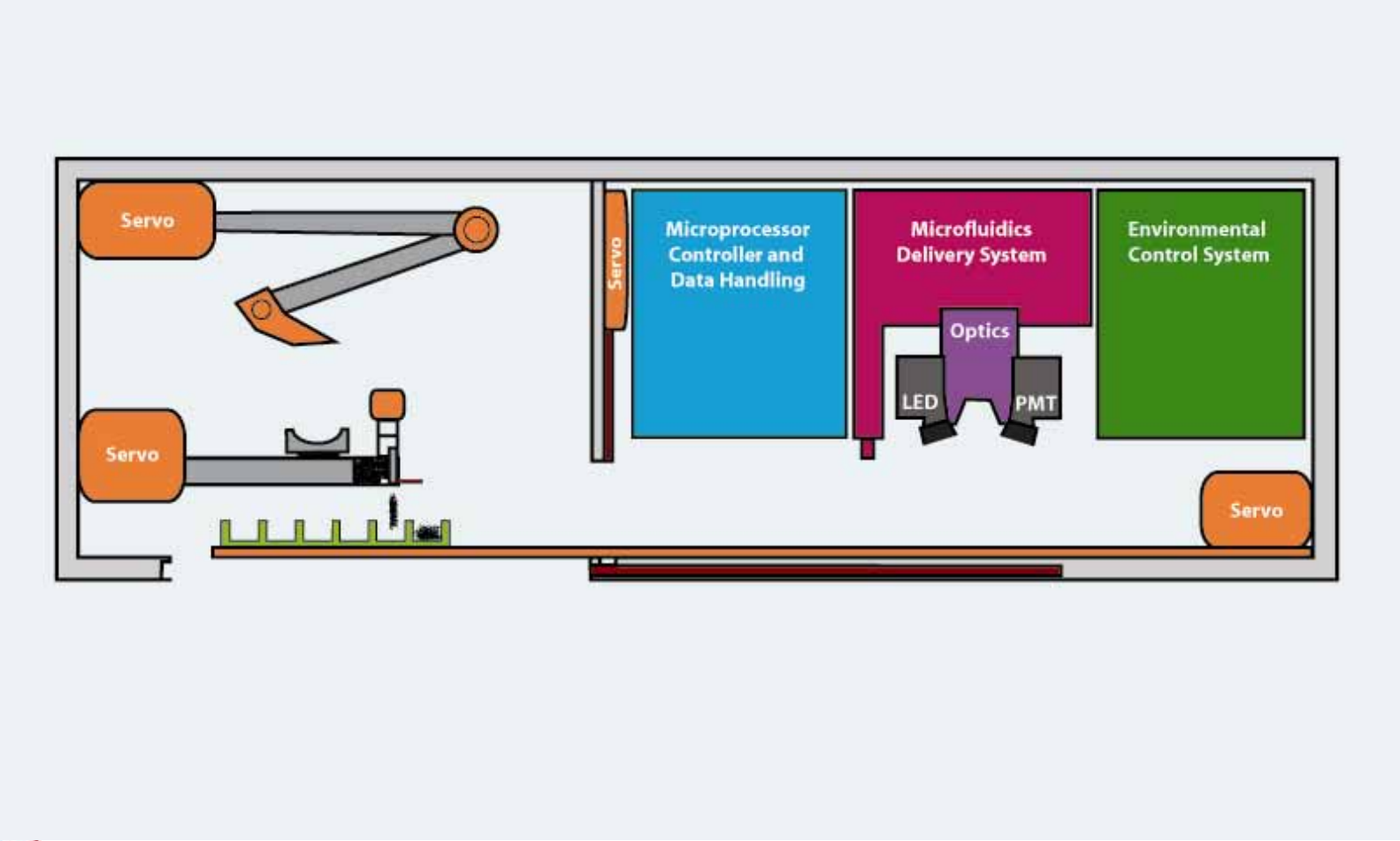


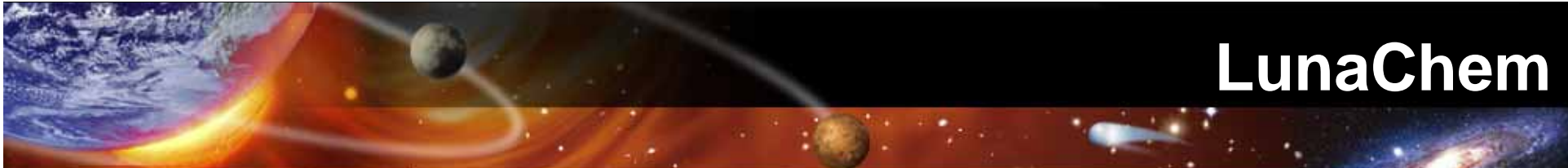
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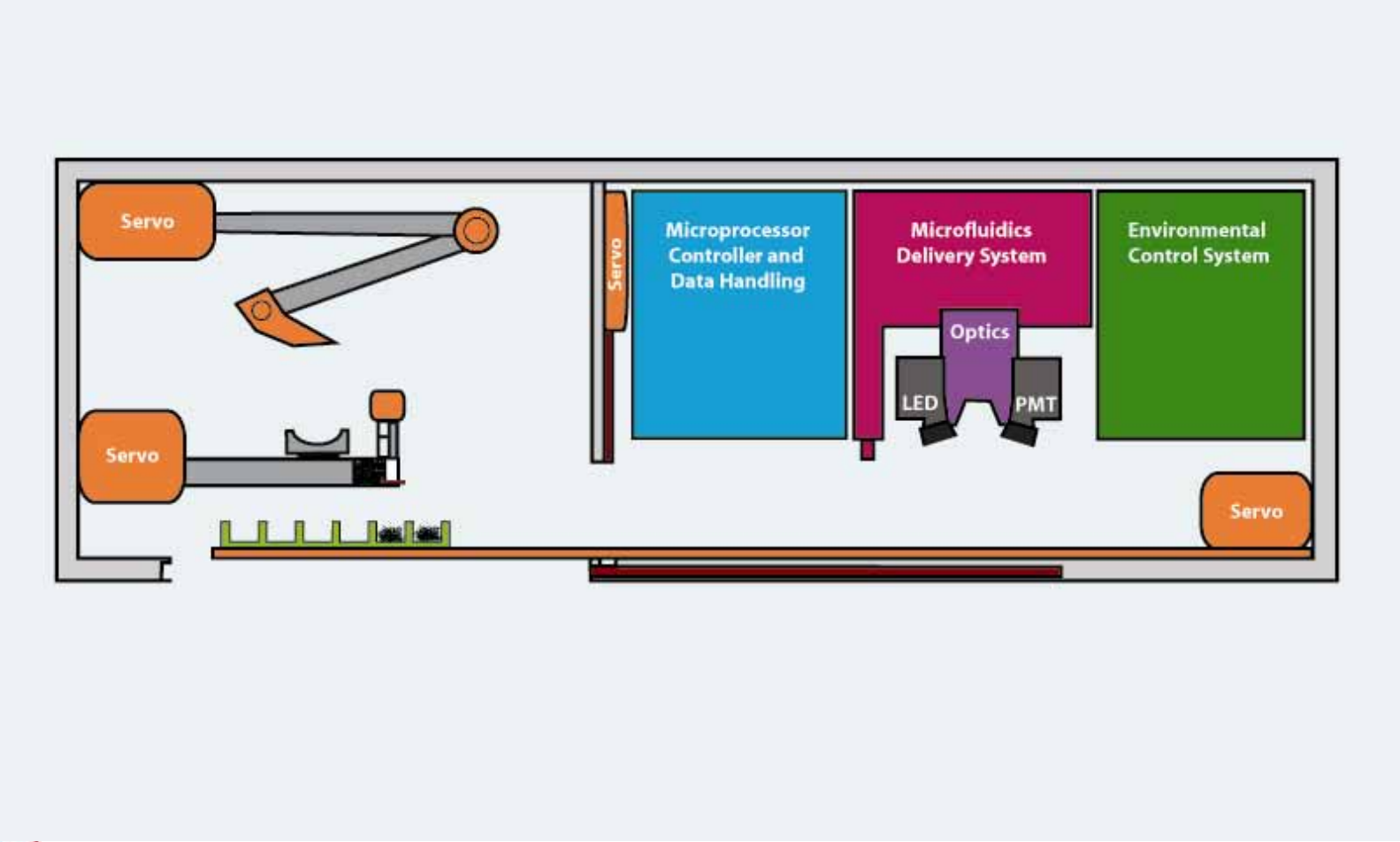


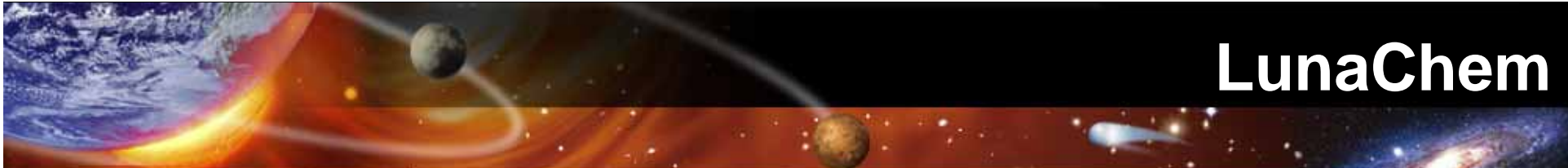
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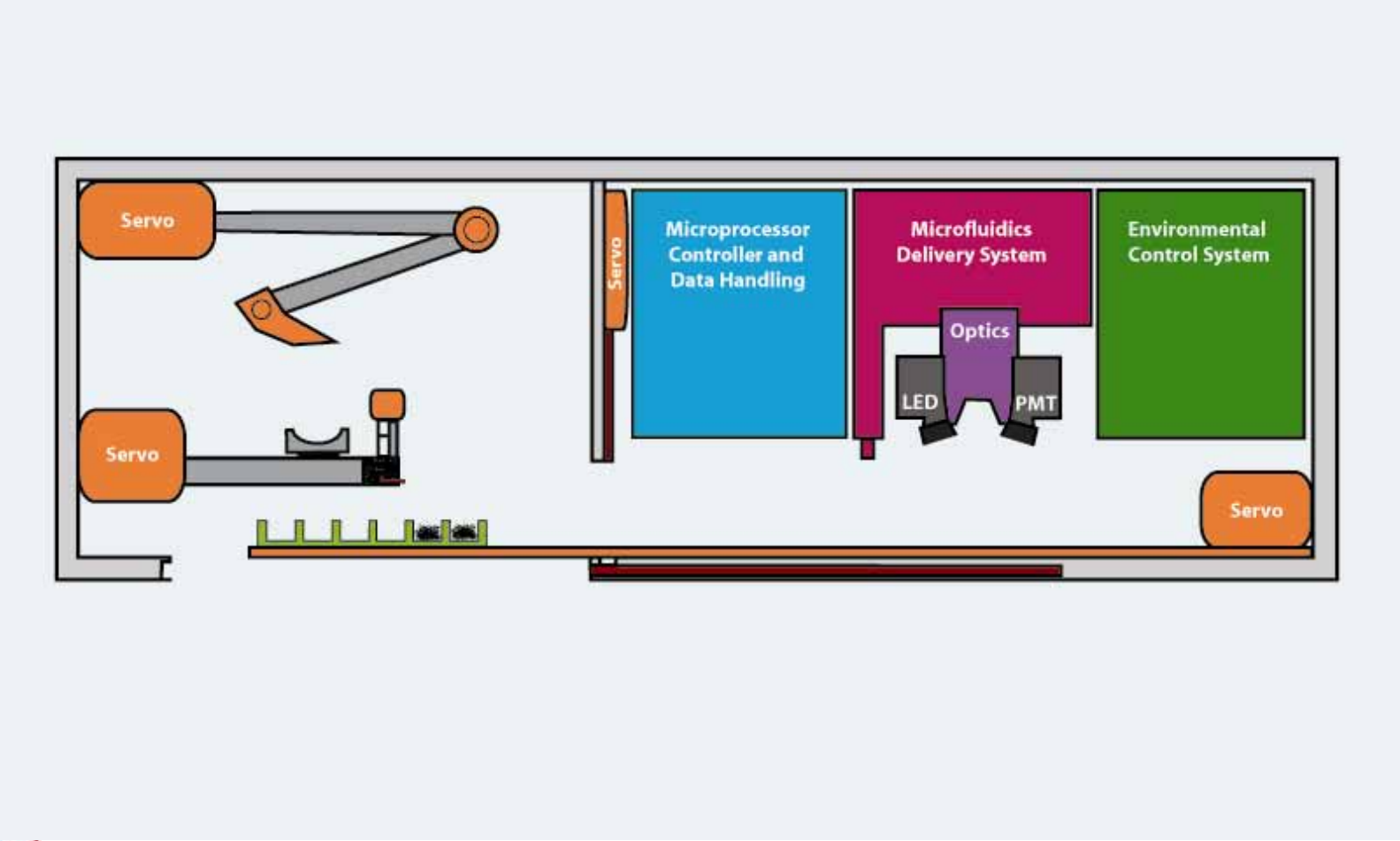


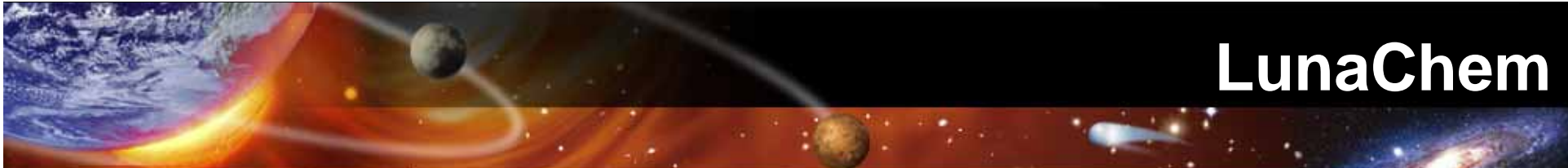
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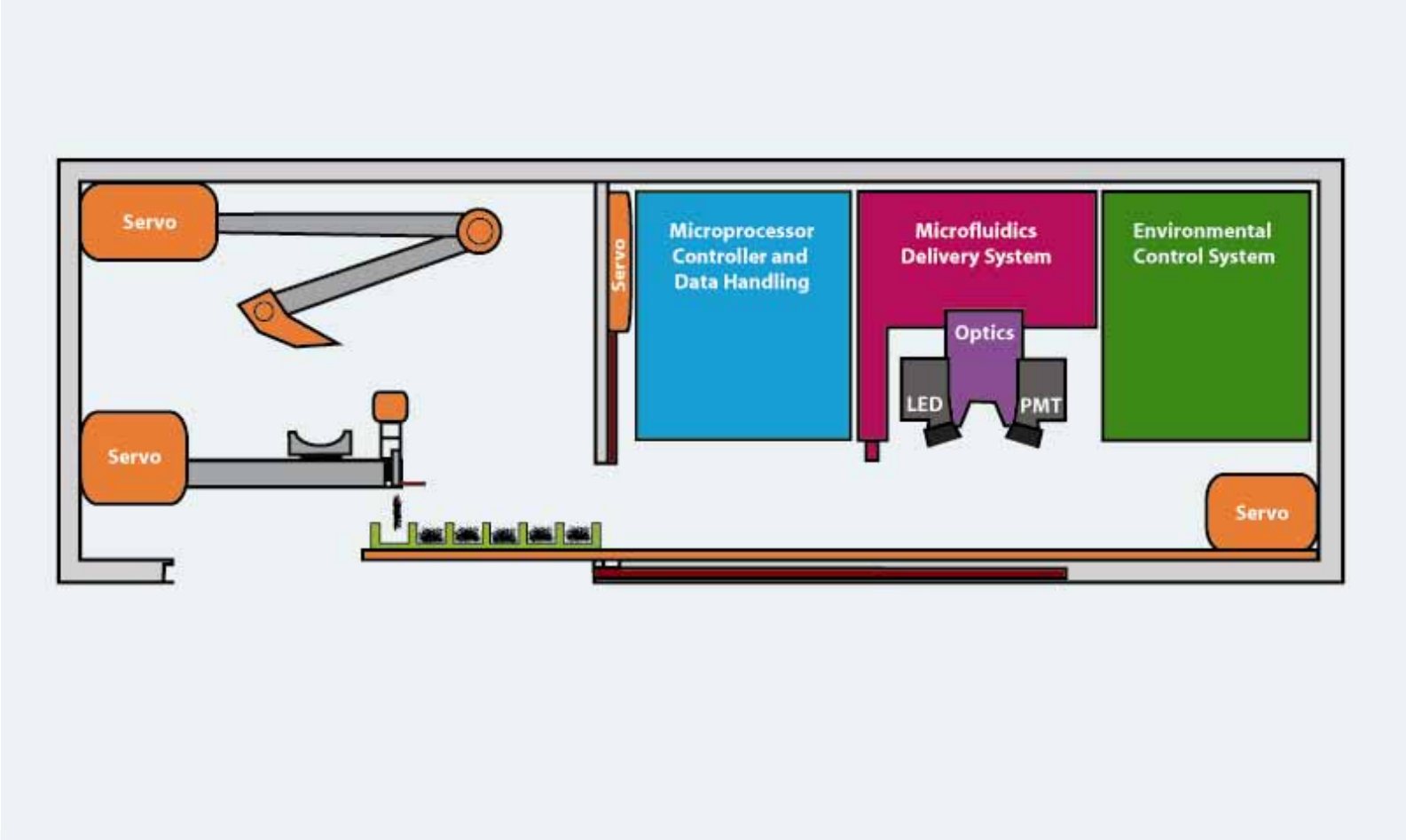


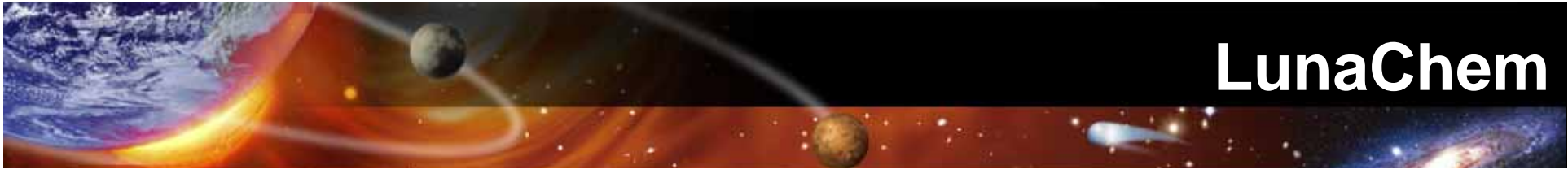
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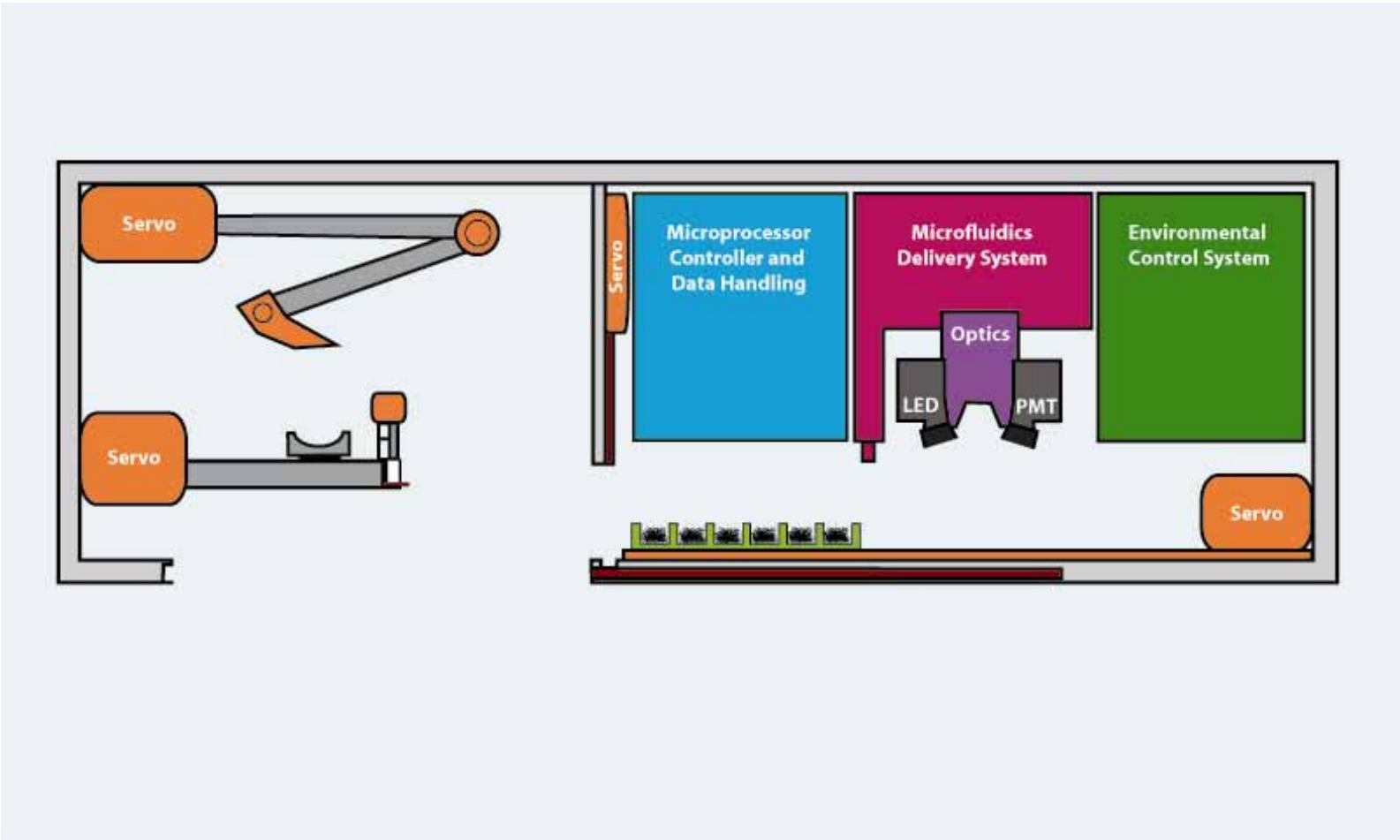


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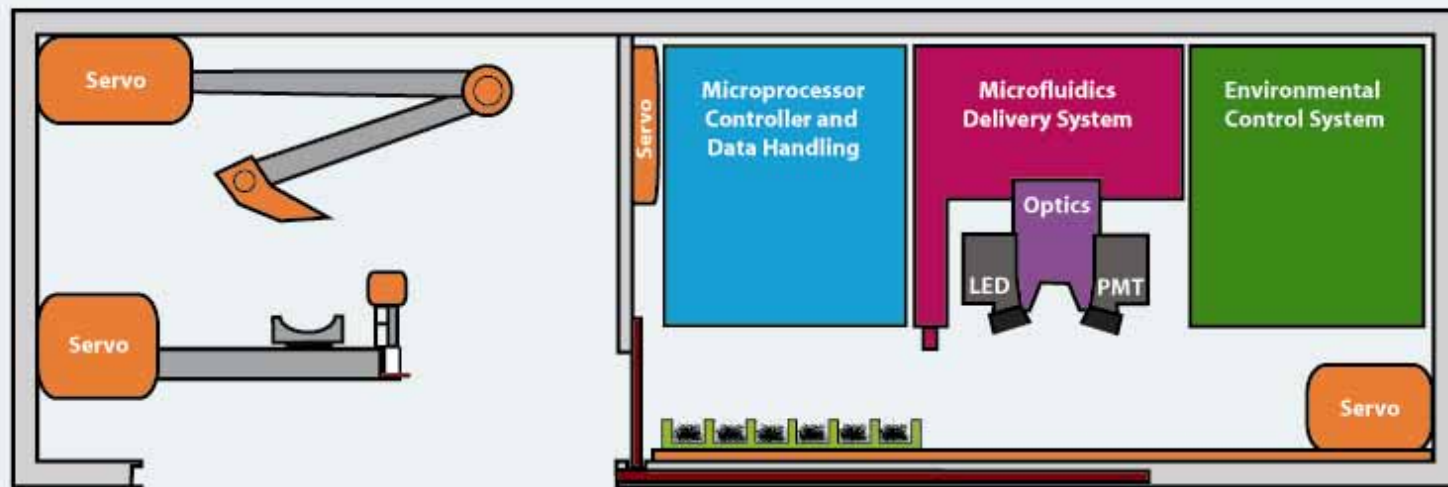




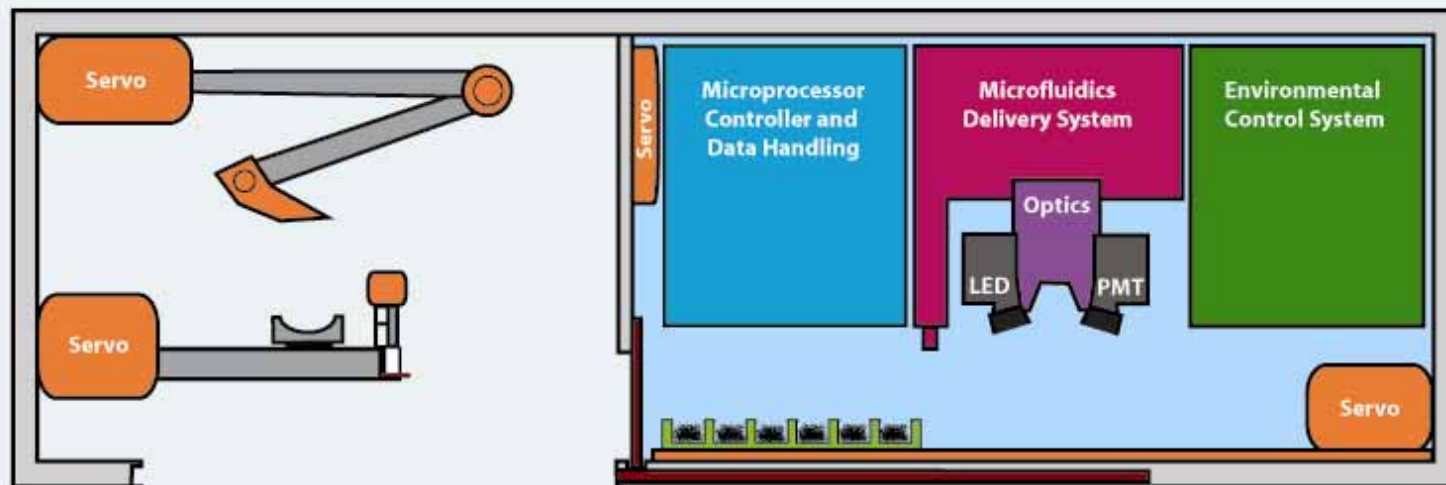
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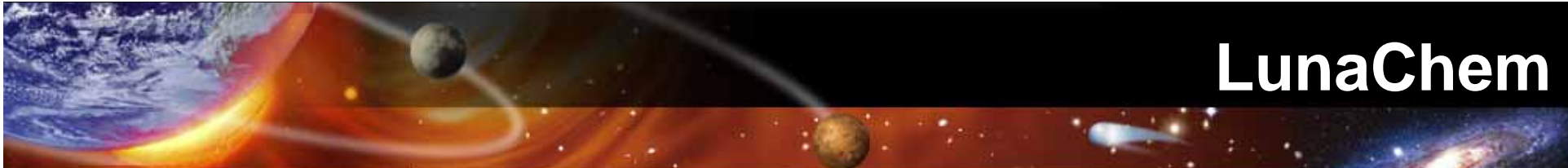


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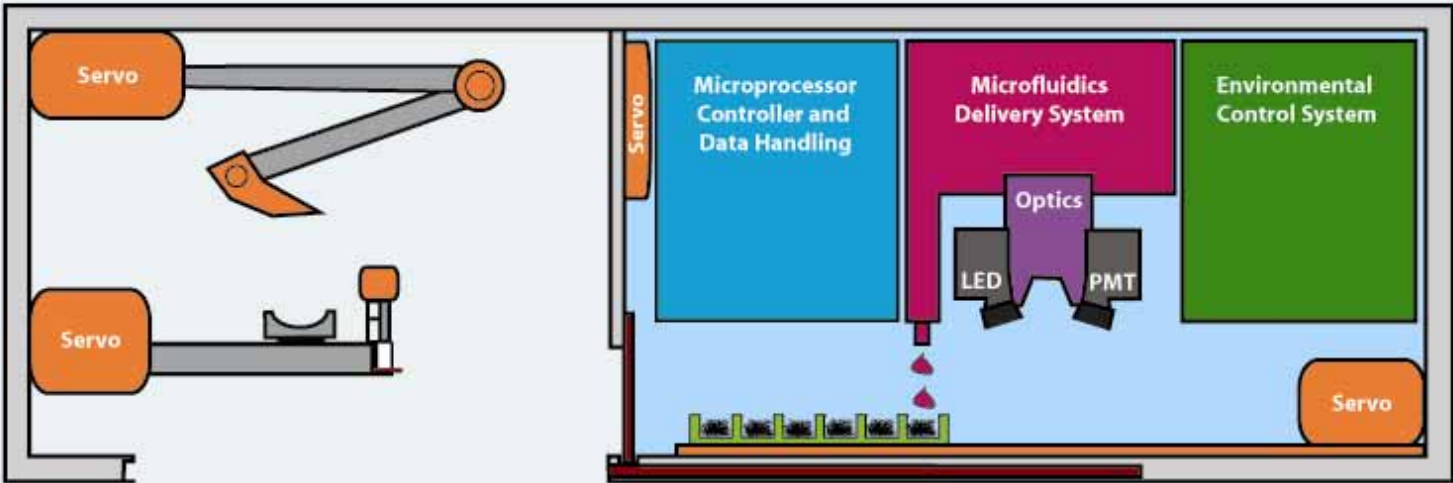


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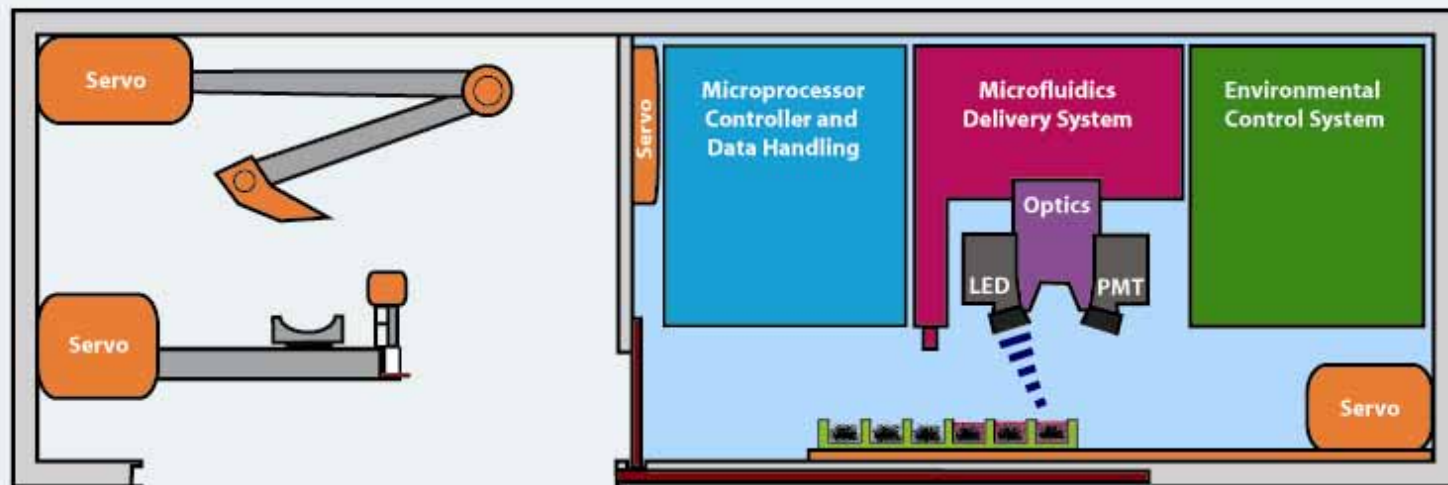
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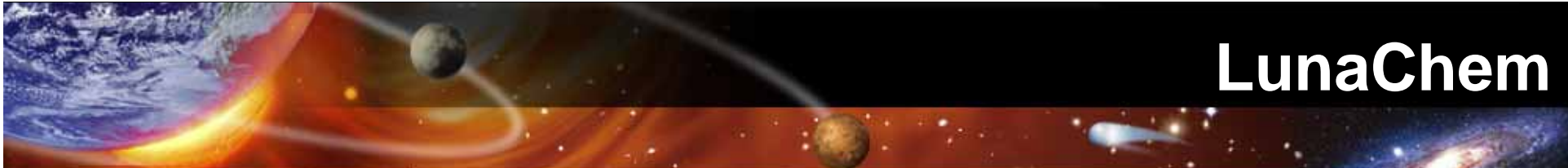


TIME 00:30 HUMIDITY 50% TEMPERATURE 25° AIR PRESSURE 1 ATM

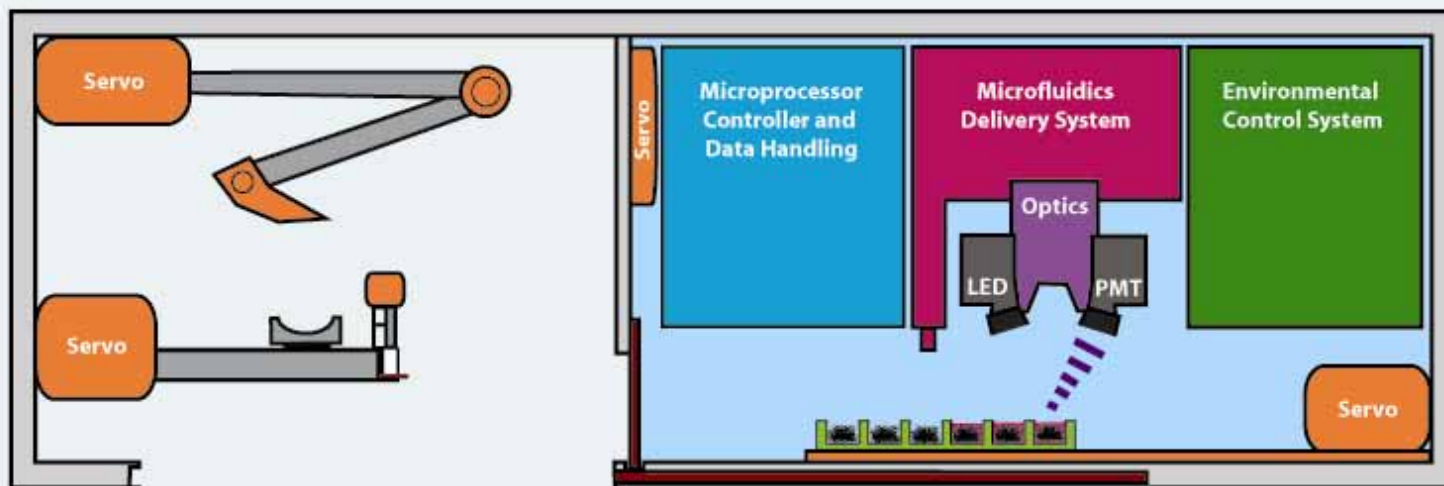


LunaChem





LunaChem



TIME 01:00

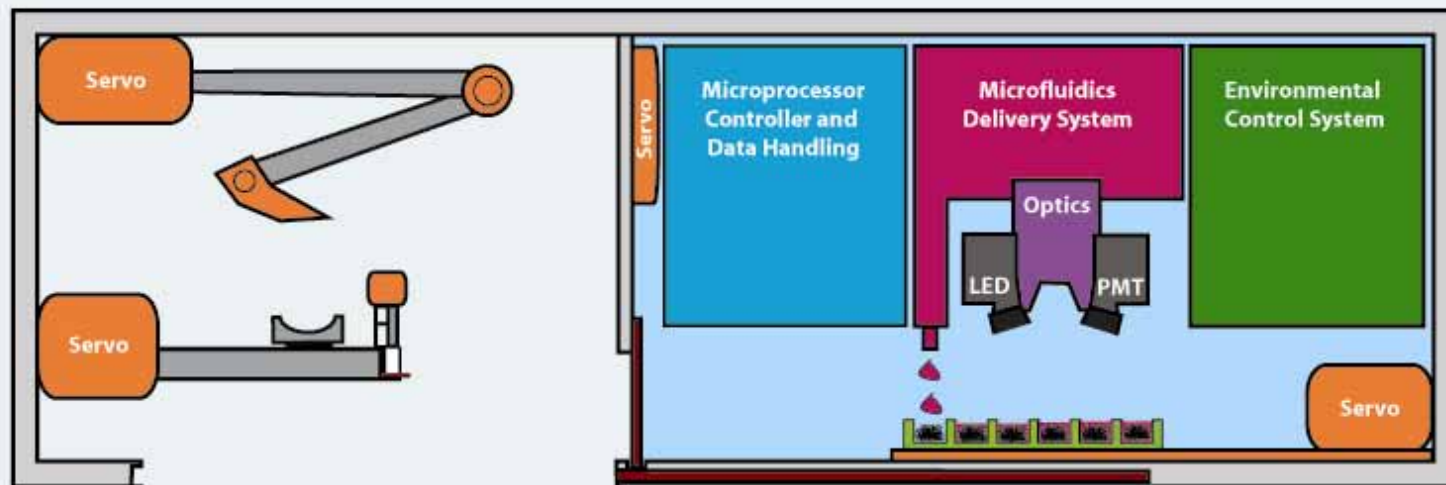
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TEMPERATURE 25°

AIR PRESSURE 1 ATM



LunaChem



TIME 48:00

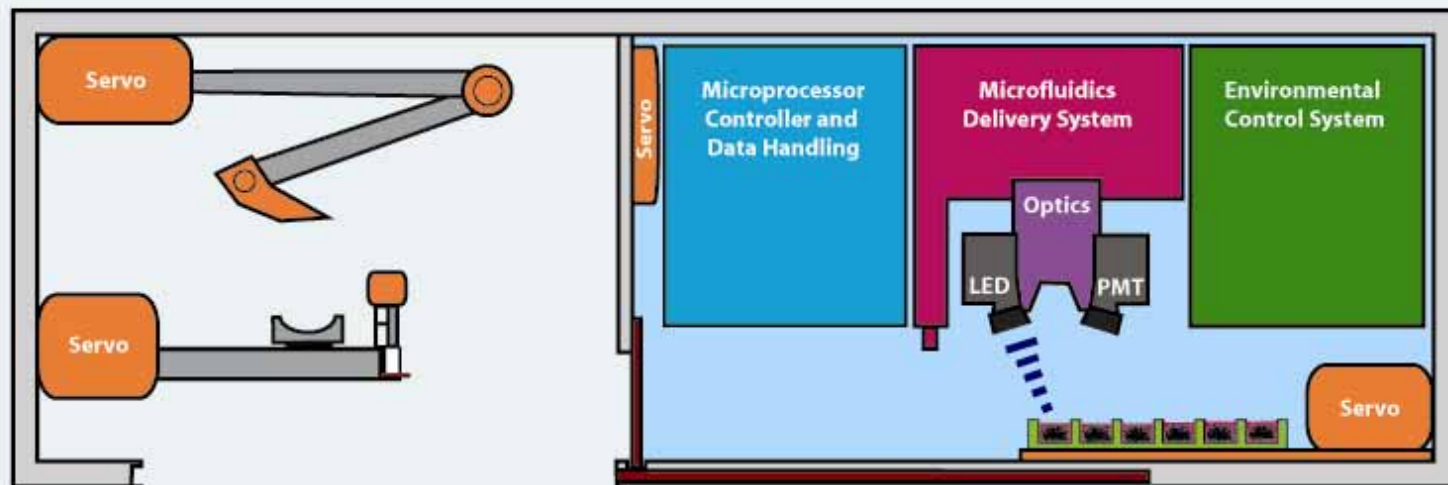
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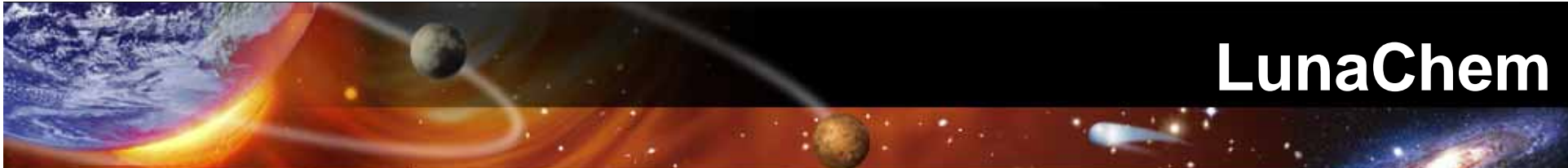
TEMPERATURE 25°

AIR PRESSURE 1 ATM

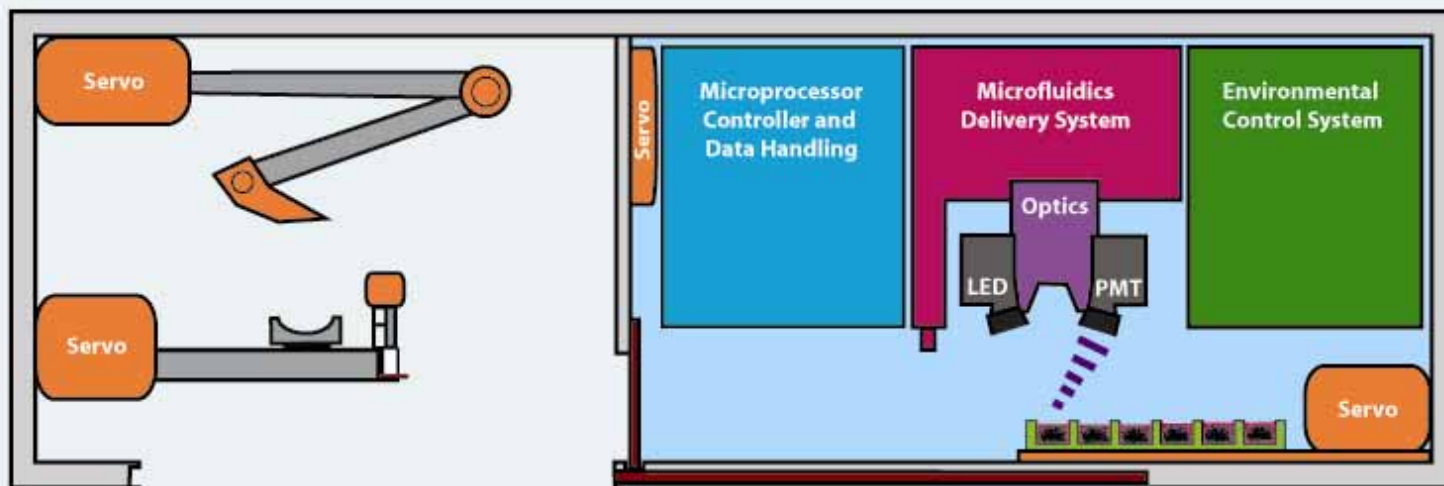


LunaChem





LunaChem

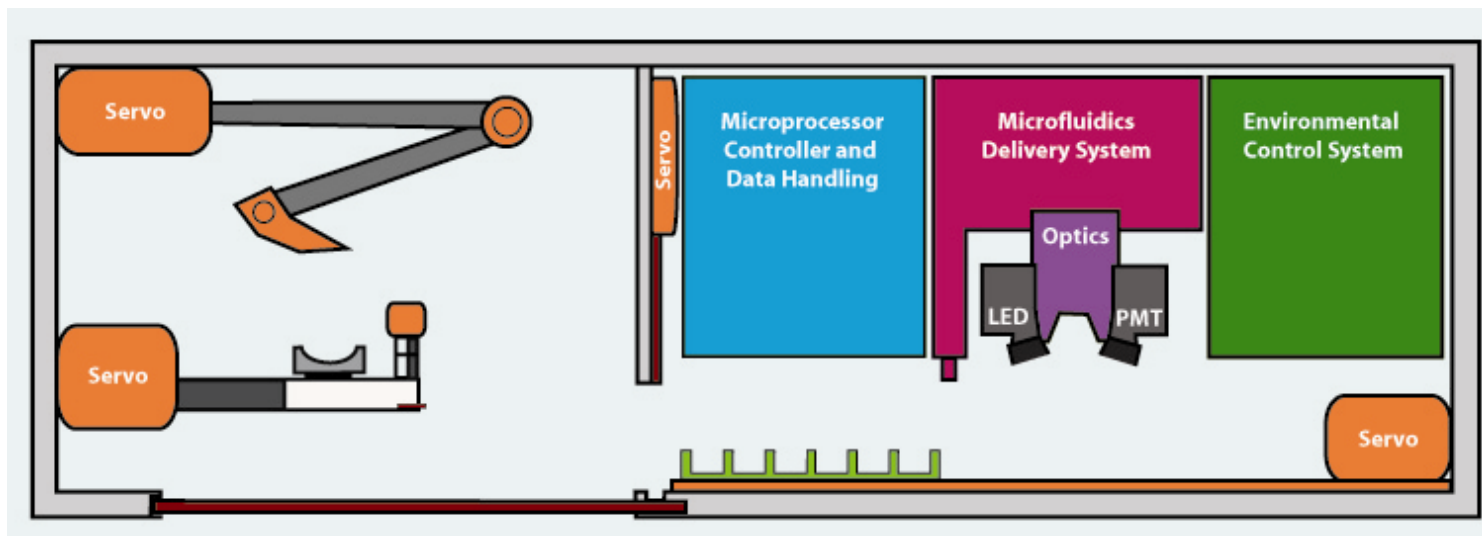


TIME 48:30 HUMIDITY 50% TEMPERATURE 25° AIR PRESSURE 1 ATM



The Two Goals of LunaChem

1. To test the chemical reactivity of lunar dust
2. To investigate the passivation (or the decay rate of the chemical reactivity) of lunar dust





How Will This Data Help Us to Safely Return to the Moon

LunaChem Fills a Critical Gap in NASA's Lunar Dust Evaluation Program		
Variables that Effect Toxicity of Lunar Dust	Can be evaluated on Earth	Must be evaluated on the Moon
Composition	Yes	No
Particle Size Distribution	Yes	No
Chemical Reactivity	NO – reactive state has been lost	YES – LunaChem will perform this experiment

- Knowing the chemical reactivity of lunar dust will:
 - Allow us to answer the single most important question about lunar dust relevant to human health and human exploration
 - Provide a key calibration of the chemical reactivity of lunar dust needed to support the work of LADTAG and DMP
 - Provide information that can be used by engineers in the design of lunar habitats





Acknowledgements

LADTAG Research Working Group

- Jon Rask
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- Larry Taylor
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- Kim Kuhlman
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- Antony Jeevarajan

National Institute of Occupational Safety and Health (NIOSH)



NASA HQ (OCHMO)



Thank-you

Questions ???

