



# Abstract #1679

English

## The Space Economic Simulator: A Unifying Vision of the Future Commercial Space Economy

Establishing a new space economy is necessary to extend mankind's reach into space and enable a new generation of space research and exploration. For decades, the technical challenges and economic benefits of creating a lunar or Martian outpost and in-situ resource utilization have been discussed, modeled, and analyzed. Now, as the private launch sector continues to grow and more commercial space companies emerge, the reality of lunar resources and permanent stations outside of Low-Earth Orbit are becoming less science-fiction and more coupled engineering-economic problems. To address these complex problems, the Committee for Expansion into Key space Industries (CENKI) has been assembled. The CENKI has created a free, open-source software framework called the Space Economic Simulator (SES), with the goal of assembling the community and technical resources to stimulate the development of a thriving new space economy. The CENKI SES is a virtual economic simulator with a focus on space-related transactions. A number of viable space industry sectors, such as cargo and human transportation, in-space manufacturing, and in-situ resource harvesting have overlapping resource and service needs that make them interdependent with one another. The CENKI SES may be used to identify new markets for in-space products and services, evaluate sensitivities to emerging technologies and regulatory policies, and spur investment into future space operations. These activities will serve to create consensus within the emerging space industry by providing a powerful shared framework for evaluating future business partnerships and opportunities. Established and start-up space companies, policy makers, and researchers may use the CENKI SES to evaluate simulated economic scenarios for technical feasibility and financial viability. The SES framework is established as a modular tool with a virtual marketplace at its center. Flexible modules, called Players, represent suppliers and customers of in-space products and services and interact with each other within the marketplace. Preprogrammed key players such as launch providers, as well as implementations of prior published studies, allow users to get started quickly and help them create their own players and space economy models. The user may then simulate how the proposed space economy evolves in the future, given the user's assumptions. The open-source nature of the SES also allows modules created by other users to benefit from data created by the rest of the CENKI community, increasing the complexity and fidelity of the economic studies and allowing groups to work together to achieve a unifying vision of the future of commercial space.

French

No abstract title in French

No French resume

### Author(s) and Co-Author(s)

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Andrew Gemer is a PhD Candidate at the University of Colorado at Boulder and a Research Assistant at the Laboratory for Atmospheric and Space Physics. His research focus involves the design, analysis, and validation of composite spaceflight instruments for in situ dust analysis. His other projects include leading the Committee for Expansion into Key Space Industries (CENKI) which performs modeling and analysis of future space economies, as well as the development of in-space manufactured batteries from renewable organic materials.

# THE SPACE ECONOMIC SIMULATOR: A UNIFYING VISION OF THE FUTURE SPACE ECONOMY



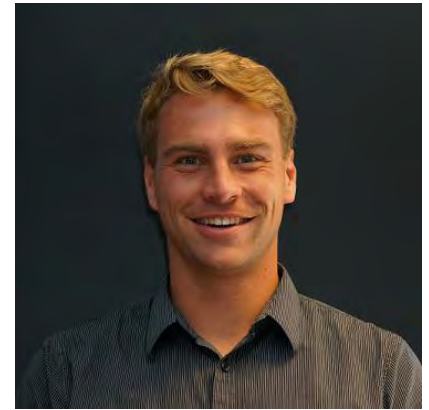
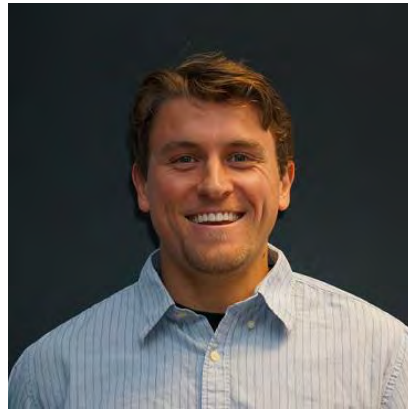
AJ GEMER  
UNIVERSITY OF COLORADO, BOULDER

PTMSS & SRR EIGHTH JOINT MEETING | 1 MAY 2017  
CANADIAN INSTITUTE OF MINING | MONTREAL, QUEBEC, CANADA

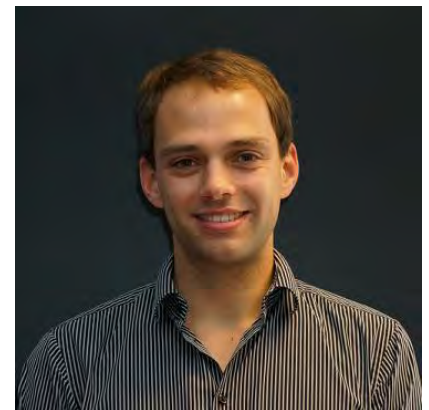
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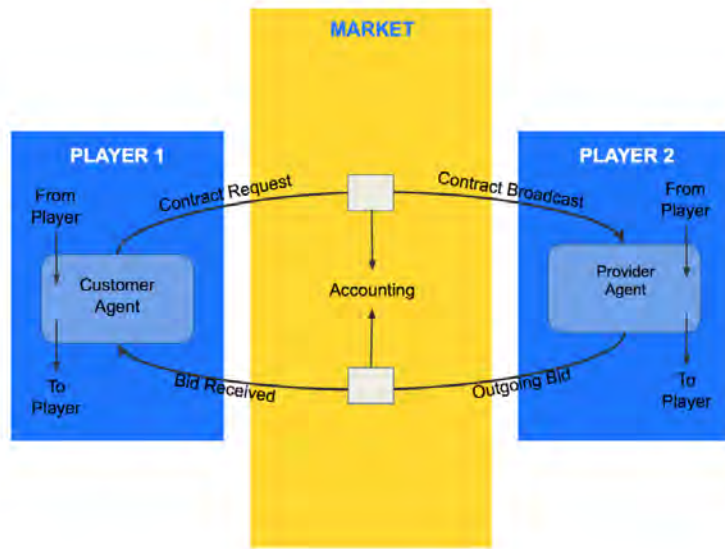
# Supporting a Space Economy



*“CENKI will assemble the community and technical resources to stimulate the development of a thriving space economy”*



# CENKI Projects

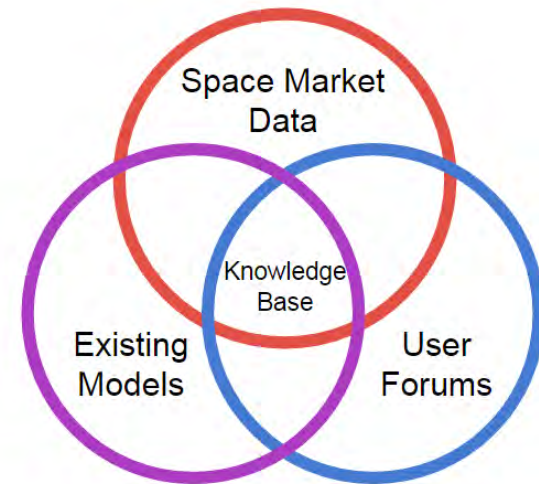


## SPACE ECONOMIC SIMULATOR

*Study, Develop, Innovate*

## KNOWLEDGE BASE

*Research, Learn, Discuss*



# Project #1

SPACE ECONOMIC SIMULATOR (SES)

# Economic Simulator Goals

**MARKET  
INTERACTIONS**

**SUSTAINABILITY  
FACTORS**

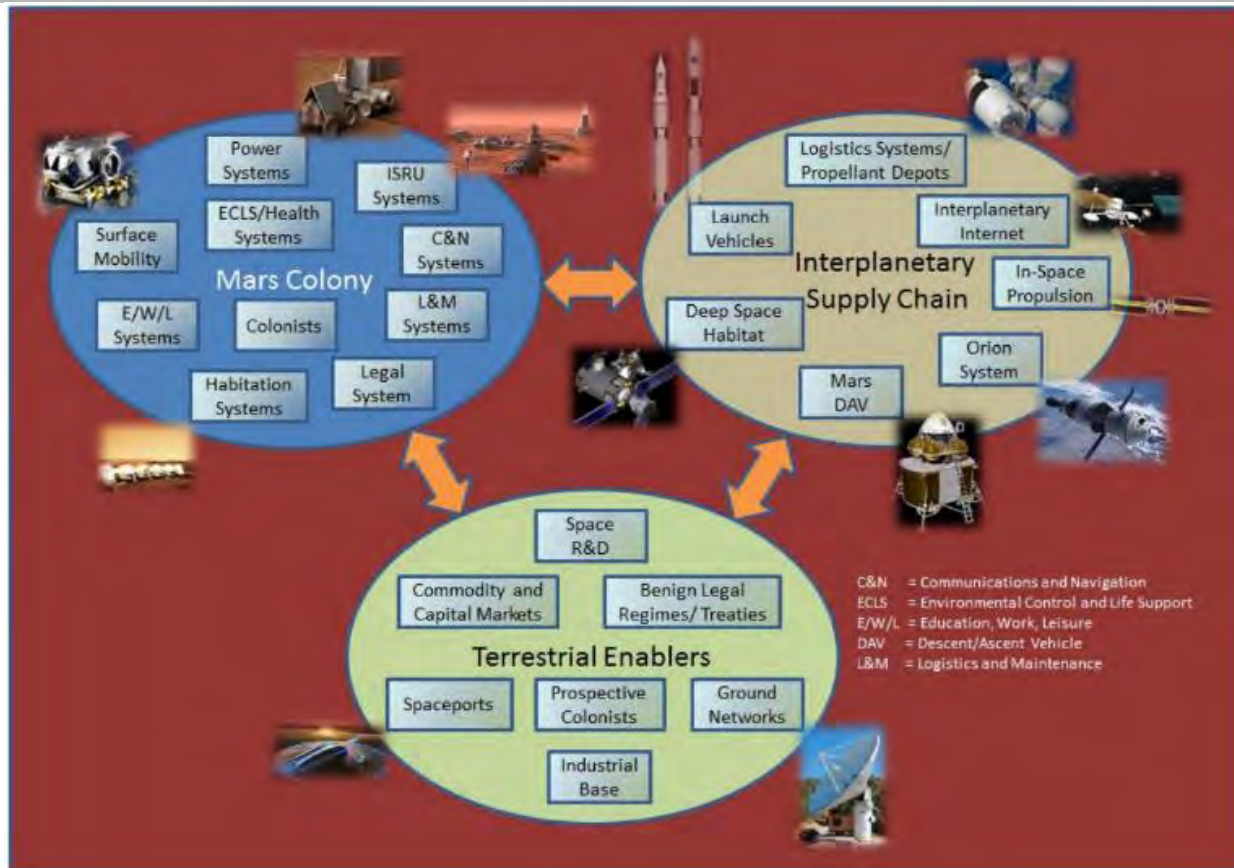
**WHAT ARE THE REQUIREMENTS FOR A  
SUSTAINABLE SPACE ECONOMY?**

**CRITICAL MASS**

**REGULATION**



# Interplanetary Supply Chain



Mars Colony Context Diagram

Figure Credit: Shishko R, Fradet R, Saydam S, Dempster A, Coulton J. An Integrated Economics Model for ISRU in Support of a Mars Colony--Initial Status Report. InAIAA SPACE 2015 Conference and Exposition 2015 (p. 4564).

# Economic Simulator Goals

## MAIN GOAL:

*Design a tool to*

***study, develop, and innovate***

*in the new space age*

## Specifically :

1. Any level user can load and run pre-configured or new studies
2. Interested users can easily develop custom building blocks which define how the economic system is modelled
3. Developers are unrestricted to create large and intricate system models to analyze any commercial space endeavors

# Agent-Based System Modelling

**Contract** - Data defining a desired resource or service

**Bid** - Provider response to contract

## **Agents**

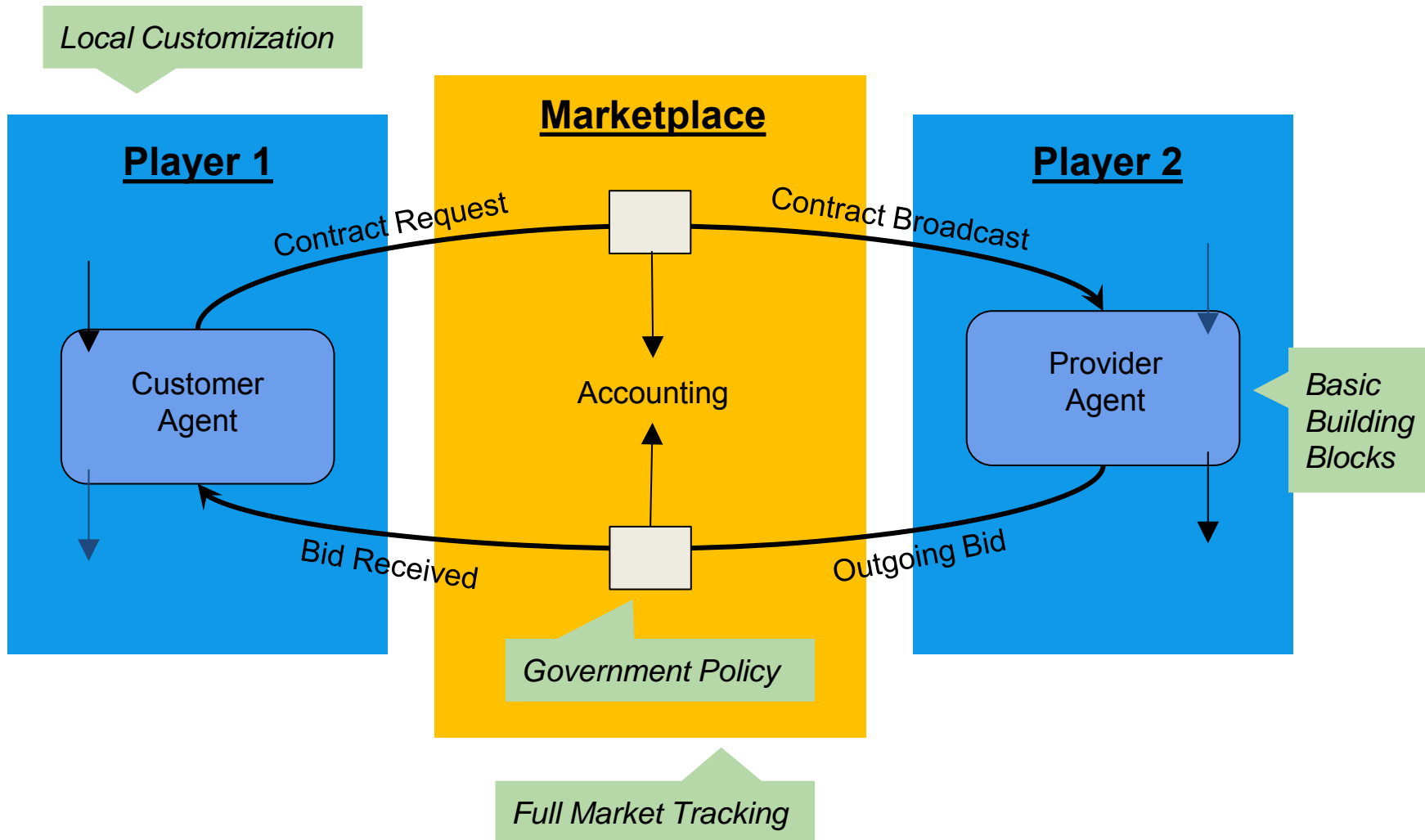
→ **Customers** submit contracts

→ **Providers** bid on contracts

**Marketplace** - Where agents interact via micro-transactions

**Players** - Individual or groups of agents and custom logic used to model the operation of a financial entity (e.g. Company, Government, Investor, Industry Sector, etc.)

# Developing Marketplace

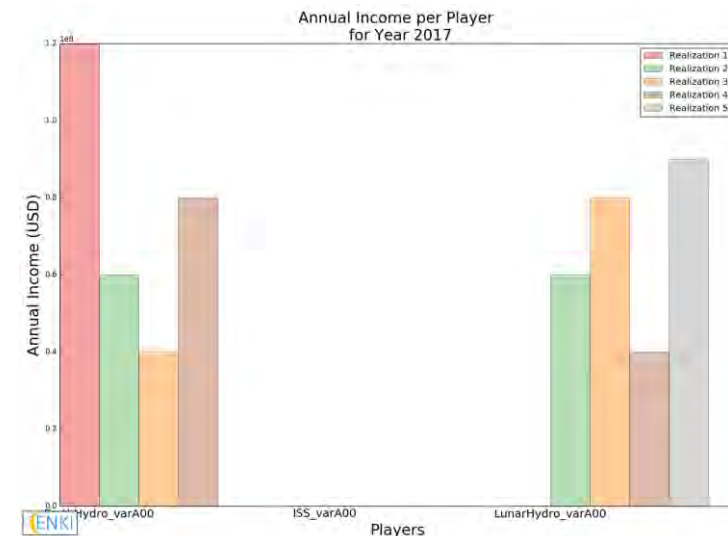
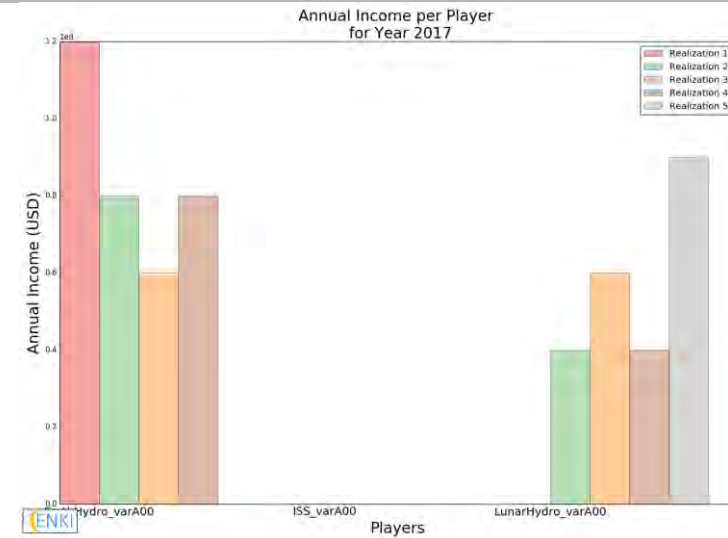
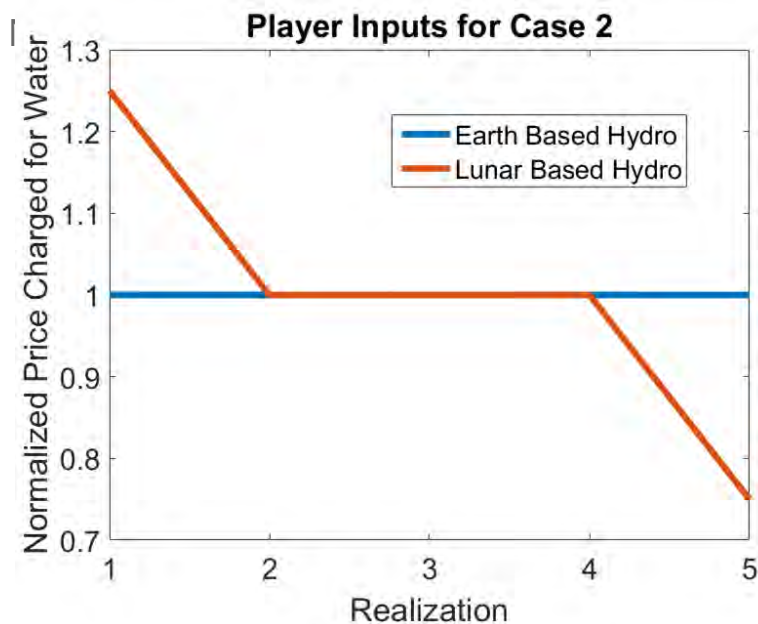


# SES Example

## Simple intro: ISS resupply of water

Single-year simulation

3 players, 6 competing contracts

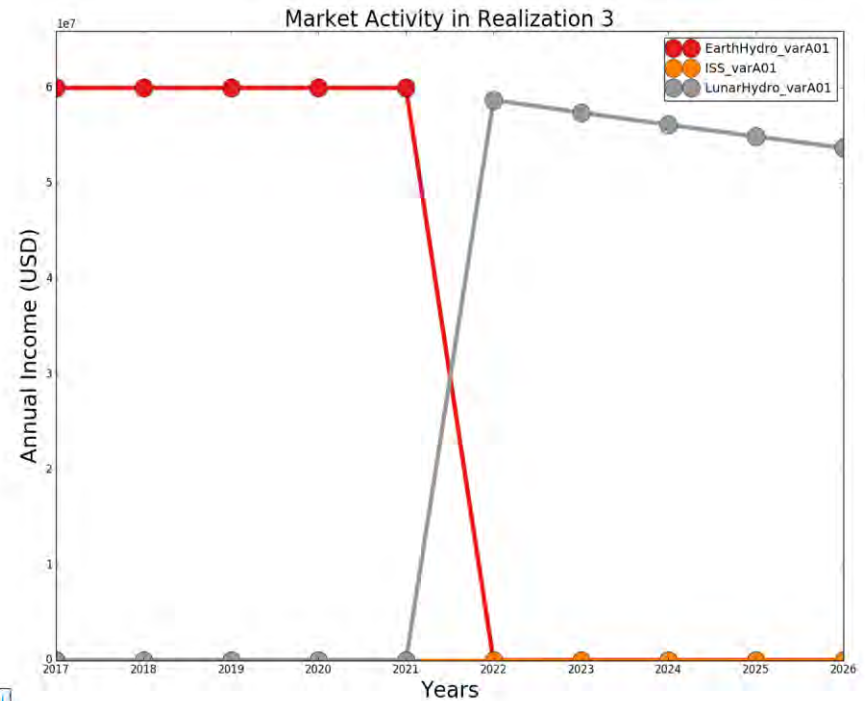
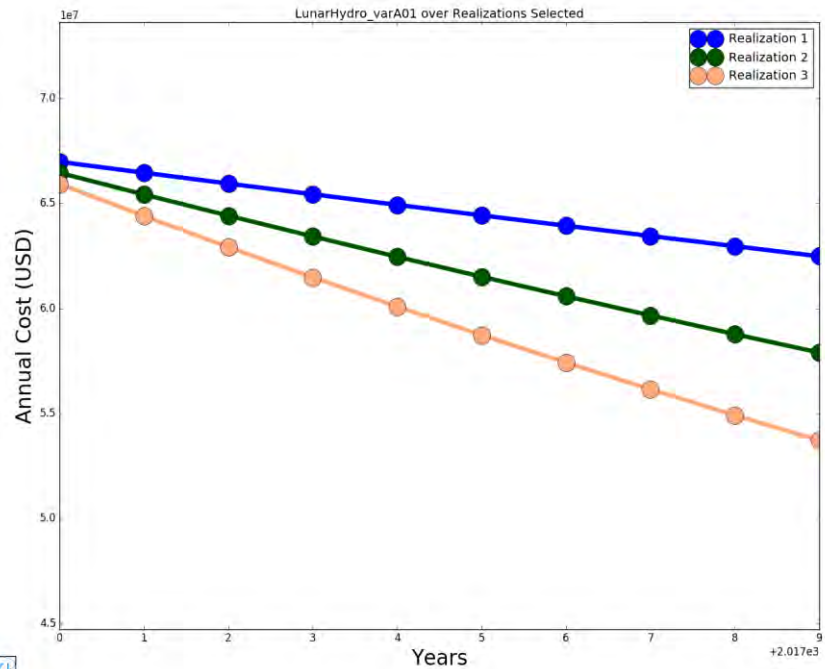


# SES Example

A simple extension: **ISS resupply of water**

10-year simulation

Lunar Hydro cost decreasing each year



# SES Example

```
MINGW64; c:/Users/AJ/ENKI
AJ@AJ-THINK MINGW64 ~/ENKI (Development)
$ python Cenki_Ses_Alpha.py ← Run SES

=====
Welcome to the CENKI Space Economic Simulator!
- Built to Support the Future -
=====

Initializing database...

Let's get started...

=====
CENKI Space Economic Simulator alpha version
- Built to Support the Future -
=====

Study Configuration
Enter:
[1] load a past study ← Load Example
[2] start a new study
>>1
```

```
MINGW64; c:/Users/AJ/ENKI

=====
CENKI Space Economic Simulator alpha version
- Built to Support the Future -
=====

Available Studies
[1] ISS_Resupply_Case_1_config.txt
[2] ISS_Resupply_case_2_config.txt
[3] ISS_Resupply_case_3_config.txt ← Load Example 3

Enter the number of the desired study configuration:
[ Ex. >>1 ]:
>>3

=====
CENKI Space Economic Simulator alpha version
- Built to Support the Future -
=====

Loading Study from: Configured Studies/ISS_Resupply_case_3_config.txt

Done.
```

# Concept User Capability

### The CENKISpace Economic Simulator

Help to Support the Player

STEP 1: Load Configuration File or Manually Configure

STEP 2: Run Simulation

Manual Configuration Sections

#### Working Directory

Select Working Directory:

#### Load Modules

Load Player and/or Policy Modules (files) or Module Packs (bundles)

#### Analysis Type

Select the analysis type and year(s) you intend to simulate:

Single Year  
Enter Year: 2016  
Check for Sensitivity Study

Multi-Year  
Enter Year Range:   
Check for Sensitivity Study

Custom Analysis Script  
Select file location and load:

### Loaded Player Modules

+ Player A  
+ Player B  
- Player C  
- STATUS: Active  
- INPUTS: Year: 2016, No. Vehicles: etc.

+ Player D

### Loaded Policy Modules

+ Policy 1  
- Policy 2  
- STATUS: Active  
- INPUTS: Income Tax: 5%, For: Everyone

### Player Level Results

- Player A  
- RESULTS: Incomes  
Annual Revenue: \$ 7 B  
Income Breakdown  
Expenses  
Annual Cost: \$ 3.3 B  
Cost Breakdown

+ Player B  
- Player C  
- RESULTS: Incomes  
Annual Revenue: \$ 10 B  
Income Breakdown  
Expenses  
Annual Cost: \$ 3 B  
Cost Breakdown

- Player D  
- RESULTS: Incomes  
Annual Revenue: \$ 3.3 B  
Income Breakdown  
Expenses  
Annual Cost: \$ 0.1 B  
Cost Breakdown

### Market Level Results

+ Reported Earnings & Expenses  
+ Policy Log  
+ Contract/Bids Log

### Results Visualizer

Figure 1 | Figure 2 | Figure 3

Annual Revenue (B)

Player A, Player C, Player D

New Figure | Plot Selected

### Plotting Tools

Custom Variable Definition / Calculations (command line)  
>>> Local "workspace" of data to plot <<<

SAVE FIGURE | Select filename to save figure too

### Message Center

(Terminal Output)

```
>> Setting: work_dir = 'C://My_Working_Directory'
>> Load Configuration File: work_dir/sim_config.txt
>> python run.py [=====] 100%
>> Simulation Complete! Elapsed time = 4.37 s
>> Output files written to working directory:
    marketplace_log.txt, sim_summary.txt
>> Plot Selected: an_rev for Player A, Player C, Player D
```



# Project #2

KNOWLEDGE BASE (KoB)

# Project Knowledgebase

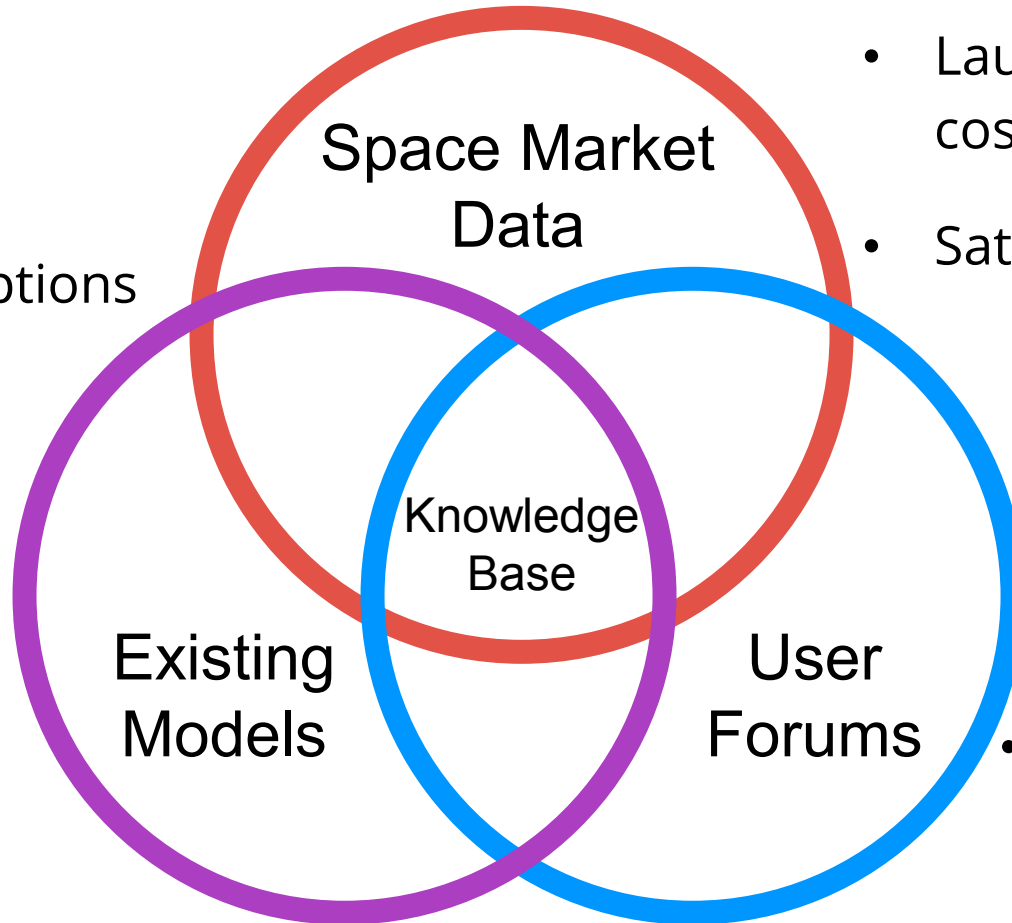
“Wikipedia of Space Economics”

1

- Launch costs/vehicles/payloads
- Satellites on orbit

2

- Summaries
- Key assumptions
- Templates



3

- Asking questions, getting feedback
- Newsletters/Digest

# Community

TECHNICAL, BUSINESS, AND POLICY

# Key Focus Areas

## Economic Modeling

**$\alpha$**  RELEASE

*Alpha - Currently Available*

- Player-Based Framework
- Competition and Complexity

**$\beta$**   
*Version*

*Beta - Planned Sept. 2017*

- Improved User Interface
- Supply Chains, Policy, and more.

## Education and Academia



*Conference Visibility*

- Interested Researchers
- Incorporation of Previous Models



*Classroom and Outreach*

- Funded to develop 2 ASEN 5519 lessons: Space Economics
- Inclusion of University talent in Engineering, Business, Economics, and Law

## Policy and Partners



*Application for FAA Commercial Space Transportation (CST)*

- Policy Analysis
- Workshops
- Competitions
- Conference Presentations

# Future Work

ALPHA VERSION

BETA VERSION

Apr May Jun Jul Aug Sep Oct Nov Dec Jan Feb Mar  
2017 2018



PRESENTATION



HACKATHON



COURSE



PRESENTATION



DEVELOPER WORKSHOP



PRESENTATION





THANK YOU!

SES Available for Download  
Sign up for our Newsletter!  
CENKI.space@gmail.com

[WWW.CENKI.SPACE](http://WWW.CENKI.SPACE)



# GET INVOLVED!

Download SES code from [WWW.CENKI.space](http://WWW.CENKI.space), check it out!

Marketing & Social Media: Help CENKI get the word out!



Come up with scenarios and use cases

Code Development: Add functionality to the CENKI framework

History of space: Knowledge Base and Forums



# SRR 2016 - Where we left off....

Extraction of lunar water has the potential to significantly impact the future of space development

There are potential near-term markets for lunar propellant

Prospecting, accessing, and utilizing this water is an important step to creating new space capabilities

Lunar water extraction will spur technological, operational, and policy development

# Prior feedback (cut this in pres)

- An idea [by Nick]:
  - Start by presenting how a custom cost model for a mining operation is easily added to a player
    - Important here to show how someone's existing model for determining operations costs of unit price charged for a resource
  - Then how other transportation and customer players are easily added from the available CENKI provided examples
  - \*\*Then how the complexities of government partnership is added with a financial player whose spending can be stochastically modelled but also biases can be easily added
- **Link cost models for operations into players, link into market of other players (like launch providers etc).**
  - **Took a lot of time to assemble our data - push Kob - have base of verifiable data ready for you to use.**

# Economic Simulator Goals

## What is my business idea's influence within the space-related economy?

1. What market interactions are necessary for my idea to be viable.

Model basic financial transactions.

Model business-specific resources and capability.

1. What market interactions are possible with the idea.

Model financial dependencies.

1. What are the overall changes to market evaluation: Gross Space Product, Costs, Resources, etc.

Model Revenue, Cost, Products, Services, etc.

## What factors drive the sustainability of a space economy?

1. What influences do government and regulatory constraints introduce?

2. What is the "critical mass" of business interests to sustain a space-related economy.