Environmental Life Cycle Assessment of Commercial Space Transportation Activities

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Overview

Environmental Life Cycle Assessment of Commercial Space Transportation Activities

• Introduction
• Objectives
• Methodology
• Expected Outcomes
• Questions
Introduction

• Commercial space transportation (CST) activities in the United States will increase operations in the next 10-15 years

• Environmental consequences are currently evaluated through National Environmental Policy Act (NEPA)
  • NEPA does not provide a cumulative assessment of environmental burden over multiple years of operation

• Environmental Life Cycle Assessment (LCA) will provide a better quantification of the life cycle environmental burden
  • Framework from International Organization for Standardization (ISO) 14040 and 14044
  • Focus is functional unit of product system
  • Addresses environmental aspects and impacts of product system
Introduction

U.S. Spaceports
Commercial/Government/Private Active and Proposed Launch Sites

Key
- FAA-Licensed
- Non-Federal Launch Site
- U.S. Federal Launch Site
- Owned by University of Alaska Geophysical Institute
- Sole Site Operator

Other spaceports have been proposed for: Alabama, Colorado, Hawaii, and Texas.

Updated January 2015
Introduction

• NASA through a Space Act Agreement (SAA) collaborates with Space Exploration Technologies Corp (SpaceX), Final Frontier Design, ATK Space Systems, and United Launch Alliance (ULA) in developing cargo and human space vehicles to support the International Space Station (4)

• Commercial industry such as Virgin Galactic with The Spaceship Company and XCOR seek to provide commercial space tourism (5)

• Federal Aviation Administration/Office of Commercial Space (FAA/AST) is the government NEPA lead for launch licenses, experimental permits, and spaceports operator licenses (6)
Objectives

• Objective #1: Conduct a base-case environmental LCA for commercial space transportation activities in the United States

• Objective #2: Conduct a sensitivity analysis to identify a range of environmental impacts

• Objective #3: Conduct additional screening LCAs incorporating “green technologies” using base-case LCA to identify potential strategies for reducing environmental impacts in commercial space activities
Methodology

Objective 1 – Base-case environmental LCA of CST activities in the United States

- Conduct literature search
- Conduct outreach to various organizations
- Apply ISO Standards 14040 & 14044
- Functional Unit: Per Launch
- Systems boundary at launch operations
  - Use and Maintenance Phases
- Identify relevant data sources
- Use tools and databases such as SimaPro Version 8.2.3 and Geographical Information Systems (GIS)
Literature Review

Types of Sources

- Peer-Reviewed Journals & PhD Dissertations
- Laws, Regulations, Policies
- Textbooks
- NEPA Documents (FAA, NASA, USAF)
- NASA Technical Reports and Information
- Related Space Systems and Technical Information
- Websites-FAA, EPA, DoD, USAF, NASA
- Interviews/Info - USAF, NASA, FAA, LCA Practicioners, PhD LCA students
Methodology

Objective 1- Environmental LCA Overall Systems Boundary
Methodology

Objective 1 - Environmental LCA Functional Unit Systems Boundary
Objectives

Objective 1 - LCA Inventory Analysis – Relevant Data

Legend:
- Red = Potential Data
- Orange = Data
- Green = Focus Phase
Methodology

Methodology

Objective 1 – LCIA - Tools (SimaPro Version 8.2.3 and Eco-Invent Version 3.3)
Methodology

Objective 1 – LCIA -- Weighting -- Delphi Method (RAND, 1950s)

<table>
<thead>
<tr>
<th>Expert Type</th>
<th>Expertise Needed</th>
<th>Organizations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Green Technology Engineers or Technicians</td>
<td>Remediation, Electricity, Waste</td>
<td>US Air Force, NASA, National Labs, Green technology contractors, DOE</td>
</tr>
<tr>
<td>LCA Practitioners</td>
<td>LCA development for various organizations</td>
<td>Independent contractors, DoD, NASA, PhD students, ESA</td>
</tr>
<tr>
<td>Academia</td>
<td>Systems Engineering, Aerospace and Rocket, Environmental, Modeling</td>
<td>UTSA, New Mexico, Institute of Mining and Technology, AF Institute of Technology</td>
</tr>
</tbody>
</table>
Methodology

Objective 1 – LCA Interpretation – Geographical Information Systems, Graphs, etc.

ESRI, ARC GIS

Radar Charts
Methodology

Objective 2 – Sensitivity Analysis

• Apply tools such as SimaPro 8.2.3 and Eco Invent 3.3 and may include Monte Carlo analysis for impact analysis

• Generate scenarios to develop a range of environmental impacts
  – Varying rocket propellant types, launch frequency, and payload types
  – Perform One at a Time (OAT) analysis of the six consumables

• Develop model to predict an environmental mission profile

• Develop methodology for identifying data needed prior to launch, during launch, and after launch, i.e., sampling strategy
Methodology

Objective 3 – Screening LCAs to Determine Green Technology Implementation Strategies

- Identify plausible green technologies where when integrated into the CST life cycle of Use phase may enhance both operations and environment (screening LCAs)

- Generate plausible scenarios to revise the base-case inventory analysis and impact assessment (2x2 Matrix)
  - Compare environmental impact of generated scenarios with base case

- Develop possible selection criteria or priority criteria of the green technology for launch operations
Expected Outcomes

- Base-case of environmental impacts for launch operations in CST activities on various propellants and five other consumables
  - Inventory Assessment
  - Impact Assessment

- Range of environmental impacts from a sensitivity analysis
  - Environmental mission profiles to possibly inform eco-design
  - Sampling strategy to aid in refining LCA models

- Plausible green technologies recommendations to integrate into the launch activities (Use phase) to potentially enhance both operations and environment
Research Timeline

- **Diagnostic Exam**: 10/23/2015
- **Comprehensive Exam**: 10/25/2016
- **Dissertation Defense**: 11/10/2017

**2015**
- **Data Analysis**: 11/6/2016 - 5/26/2017
- **Dissertation Writing**: 5/27/2017 - 9/8/2017
- **Preliminary Research**: 7/12/2015 - 8/7/2015
- **Interviews, Networking**: 9/9/2015 - 9/16/2017
- **Dissertation Proposal**: 7/10/2016 - 10/16/2016
- **Grant Proposal**: 4/2/2017 - 8/6/2017

**2016**

**2017**

Microsoft Office timeline
Questions?

Thank you
CST Key Players
Not all inclusive
References
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• (6) http://www.faa.gov/about/office_org/headquarters_offices/ast/environmental/nea_pa_docs/; accessed 10/15.
References

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• (7) Company Logos from each of the companies websites, accessed 9/16.


References
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• (12) Screenshot of current SimaPro Version 8.2.3 Database, accessed 10/16.


• (15) Scenario Matrix: https://images.search.yahoo.com/search/images; source is: Moriarty, P.; Batchelor, C.; Abd-Alhadi, F.; Laban, P.; Fahmy, H.; INWRDAM (Editor) (2007); accessed 10/16.