Environmental Life Cycle Assessment (ELCA) of Commercial Space Transportation (CST) Activities in the United States

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OVERVIEW

- Introduction – Problem Statement
- ISO 14040 Life Cycle Assessment (LCA)
- Base-case Rocket Launcher Results
- Space Transportation Environmental Profiles for Launch (STEP-L) in the Use Phase
- STEP-L Dashboard – Operational LCA
- Summary

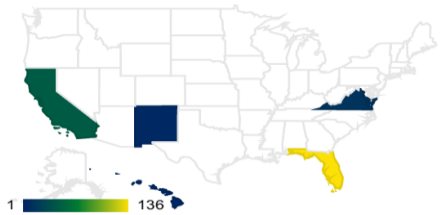
(1)

INTRODUCTION – LAUNCH ACTIVITY

Licensed Launches

249

Total Launches since 1989



11

FY 2016

8

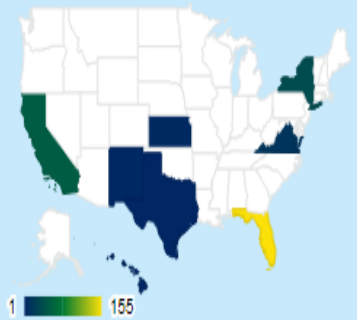
CY 2016

August 2016 data

Licensed Launches

281

Total Launches since 1989



14

FY 2018

6

CY 2018

23

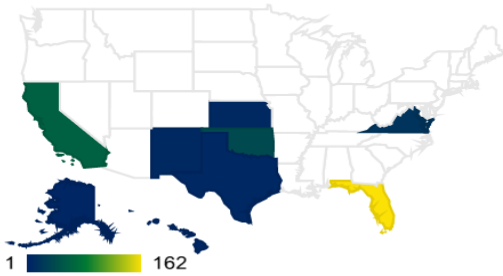
Active Licenses

March 2018 data

Licensed Launches

299

Total Launches since 1989



32

FY 2018

24

CY 2018

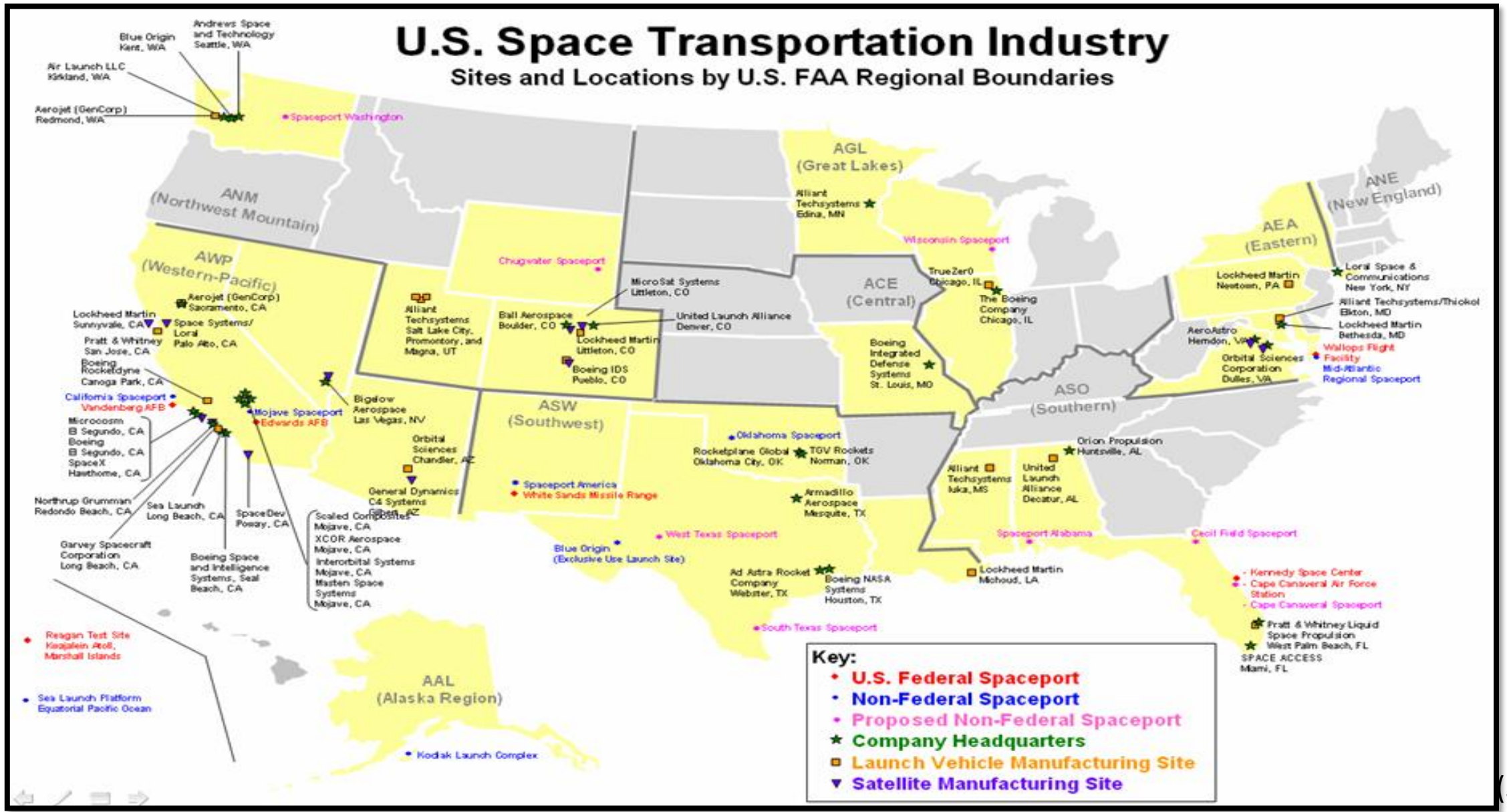
24

Active Licenses (licenses/)

September 2018 data

(2)

INTRODUCTION – COMPREHENSIVE NATURE



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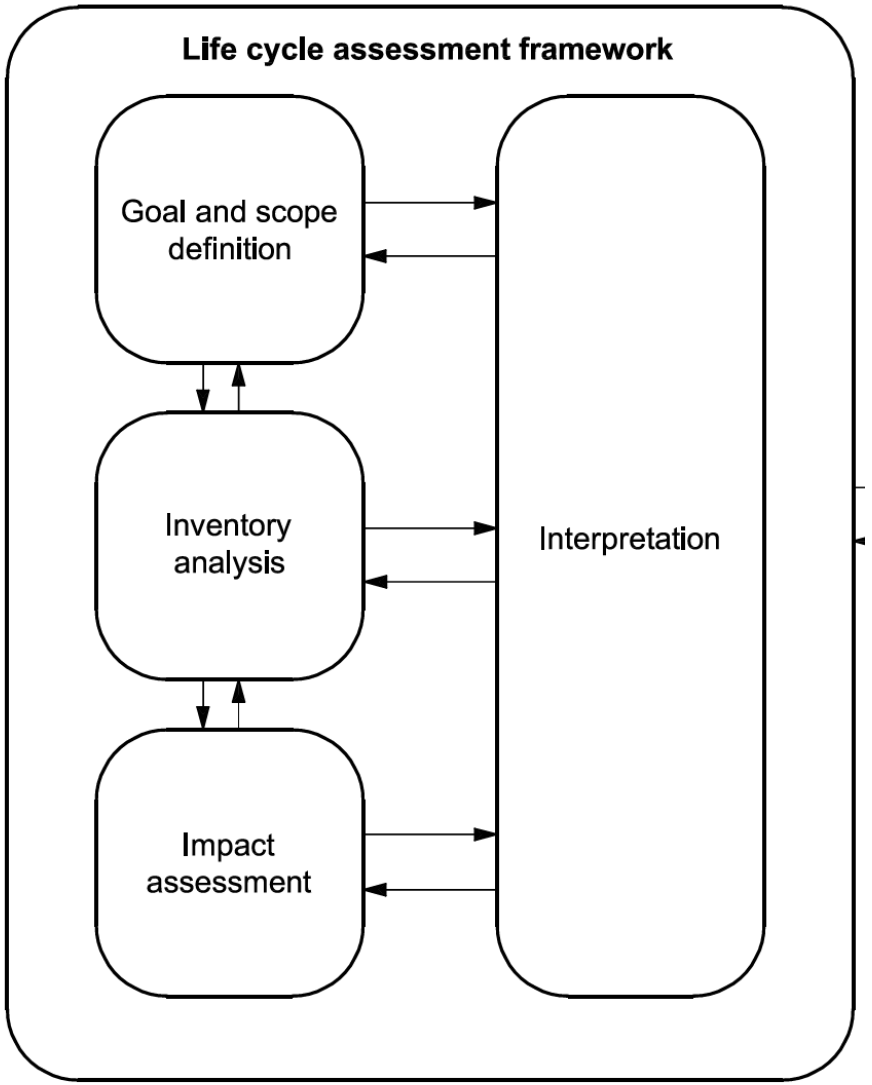
LIFE CYCLE ASSESSMENT FRAMEWORK – ISO 14040, 14044 (2006)



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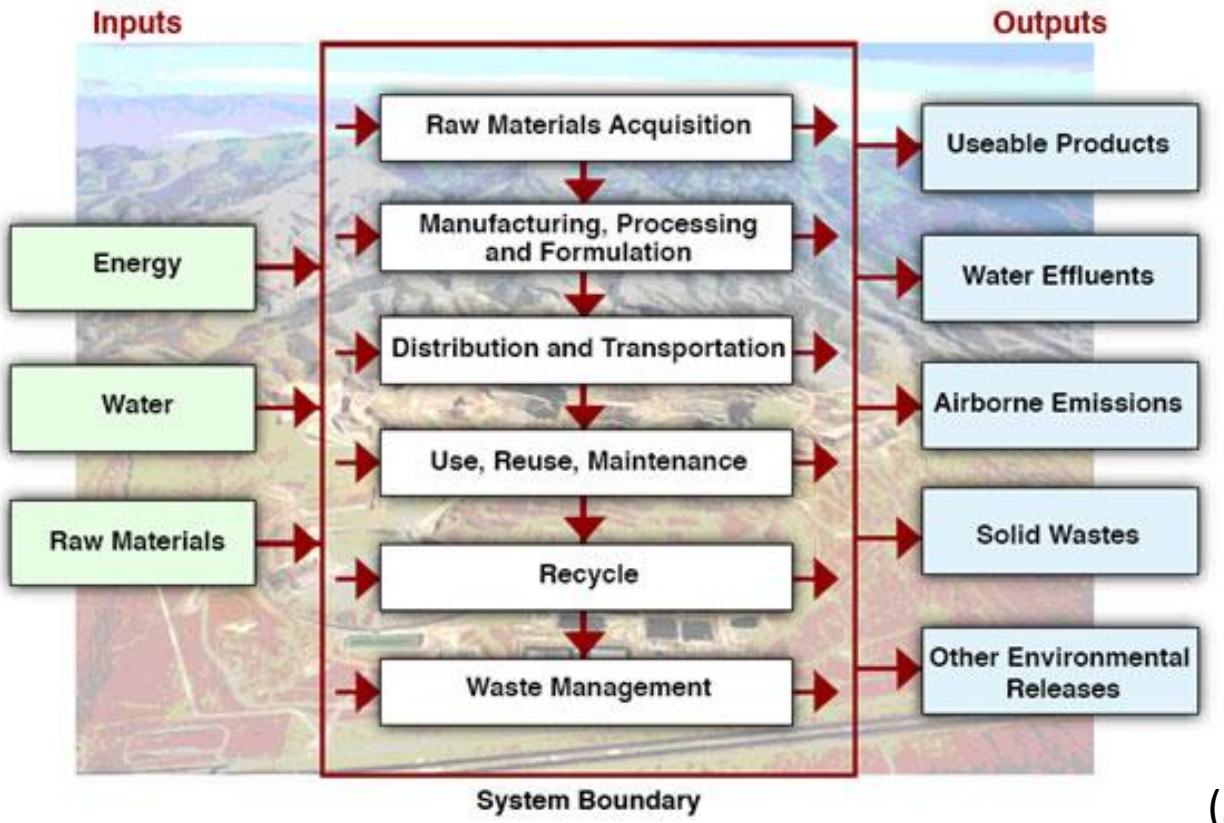

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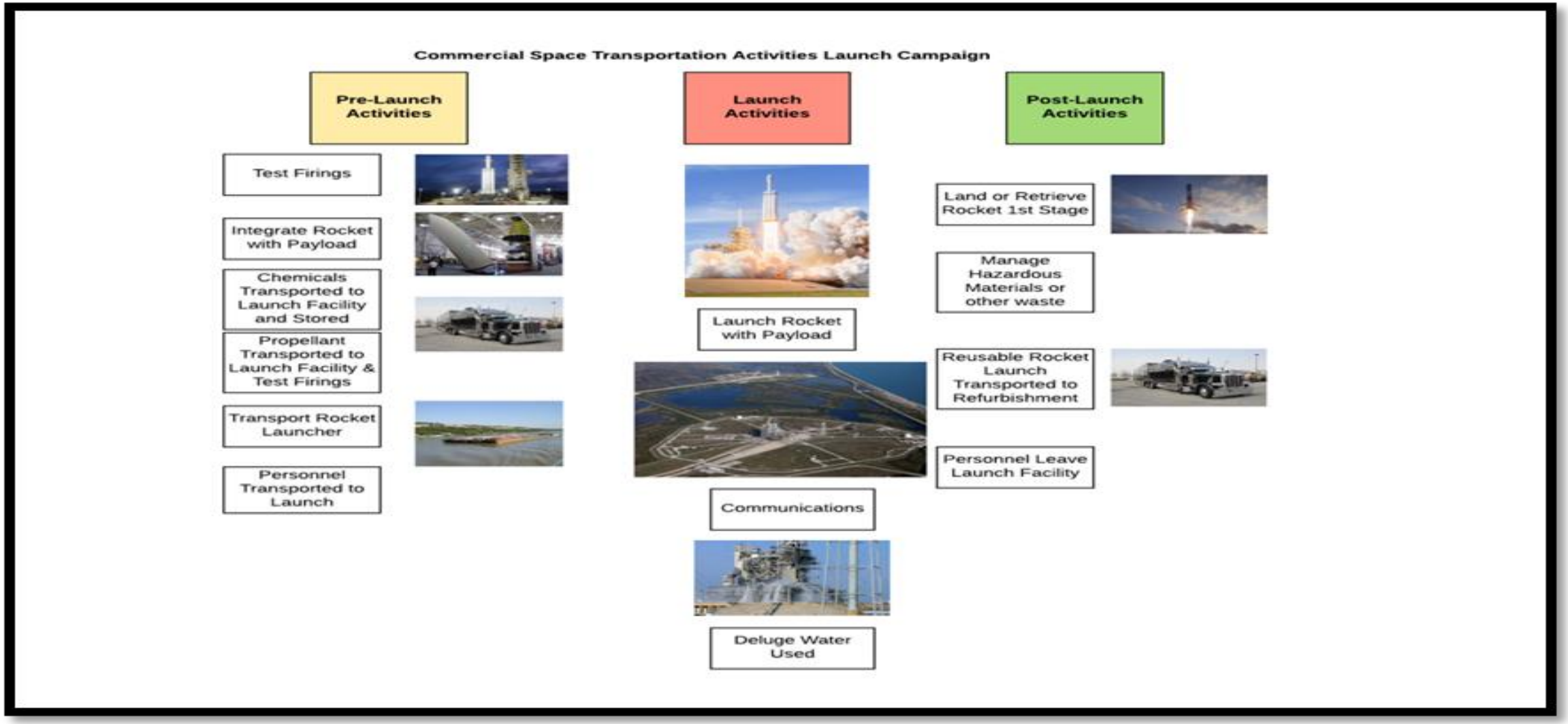
GENERIC LAUNCH CAMPAIGN ACTIVITIES



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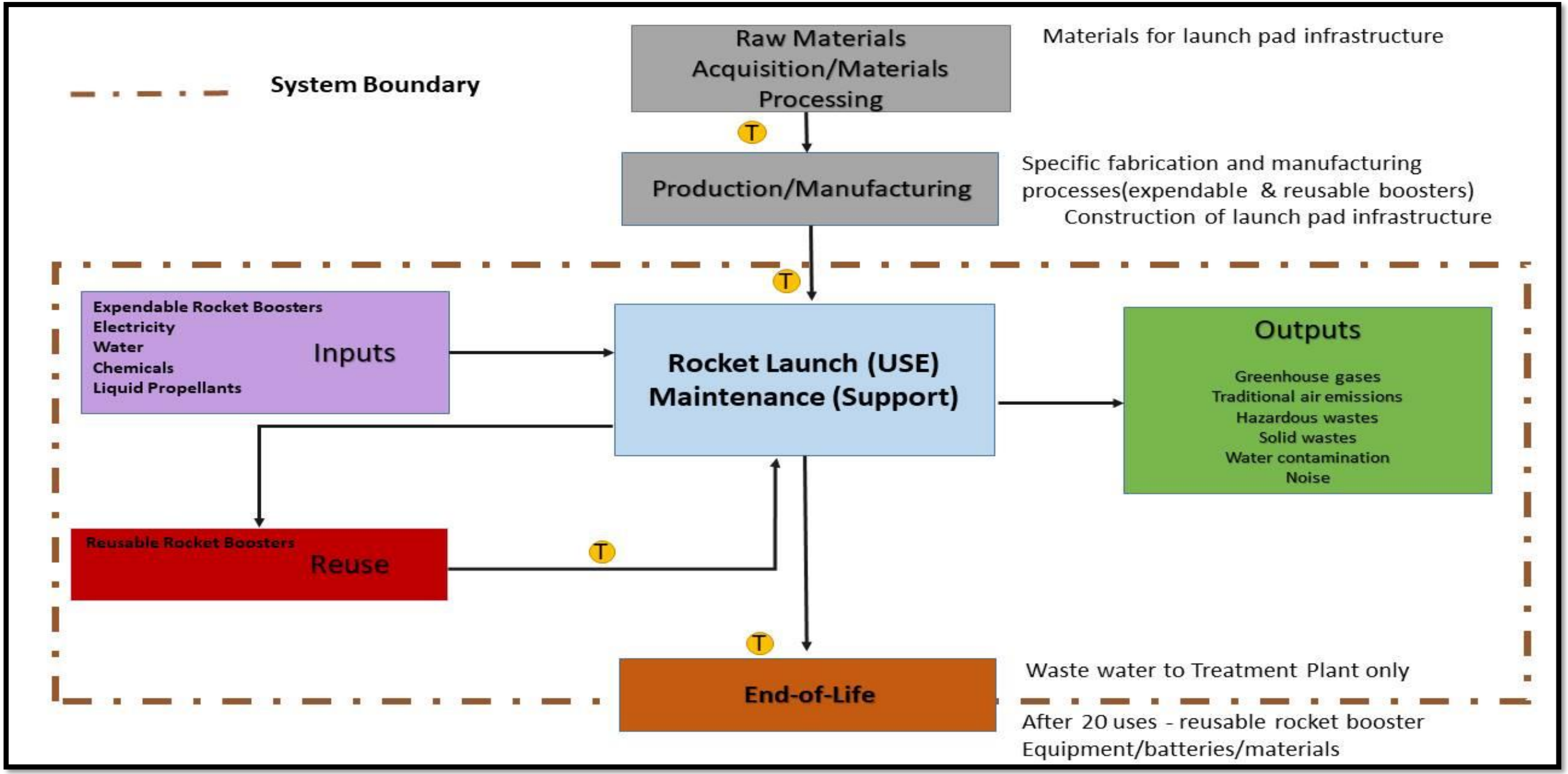
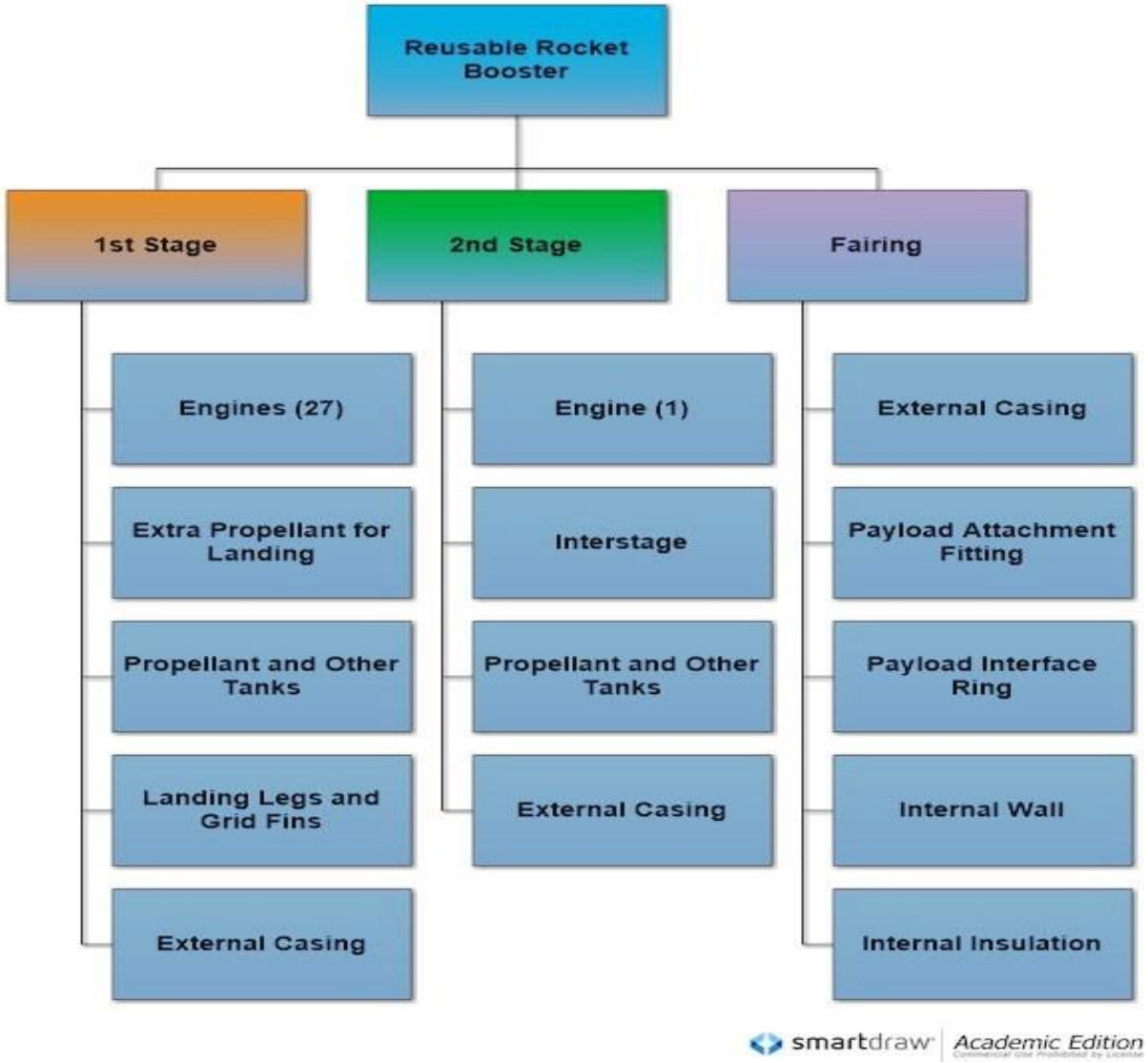
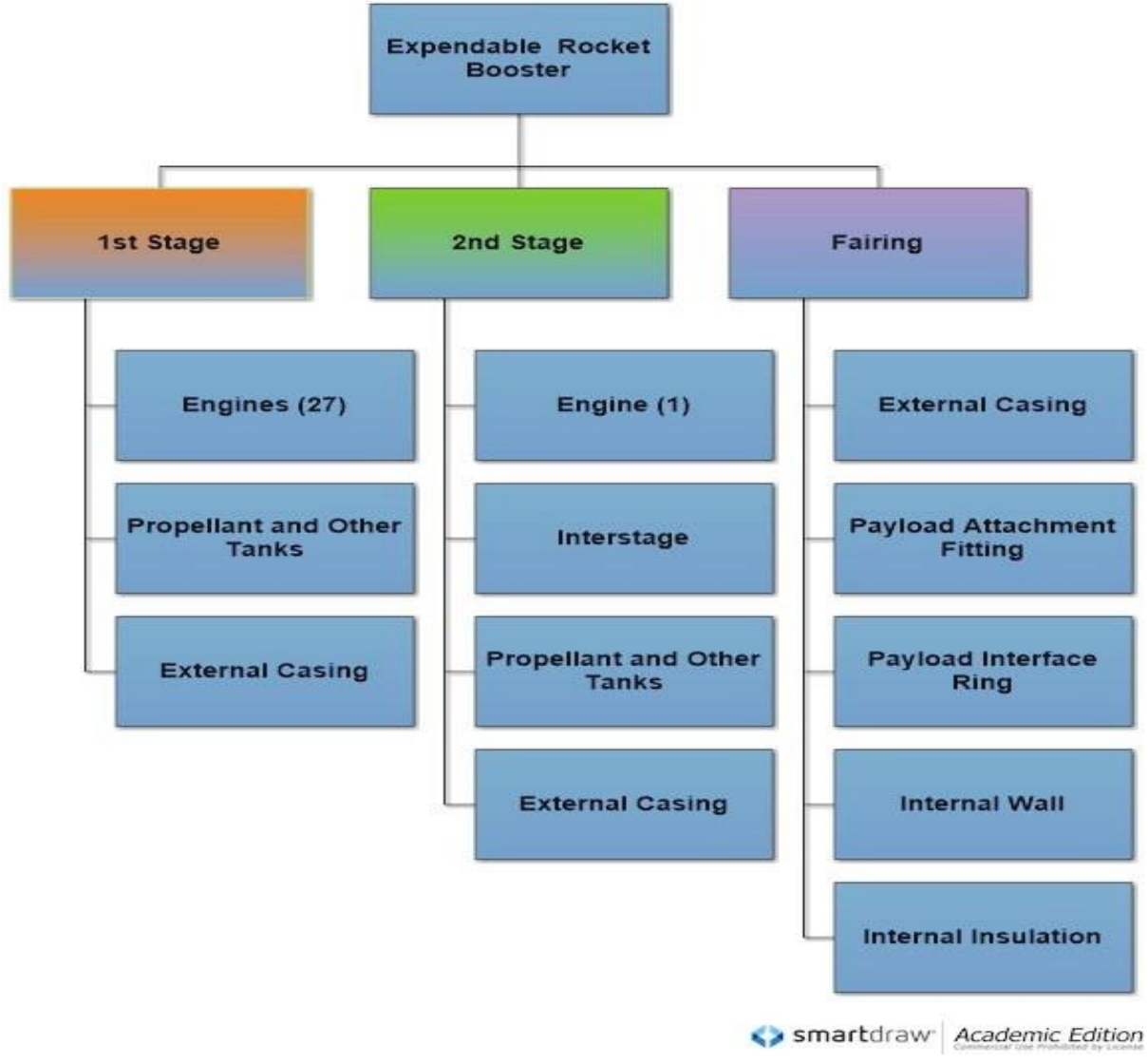
ELCA OVERALL SYSTEMS BOUNDARY

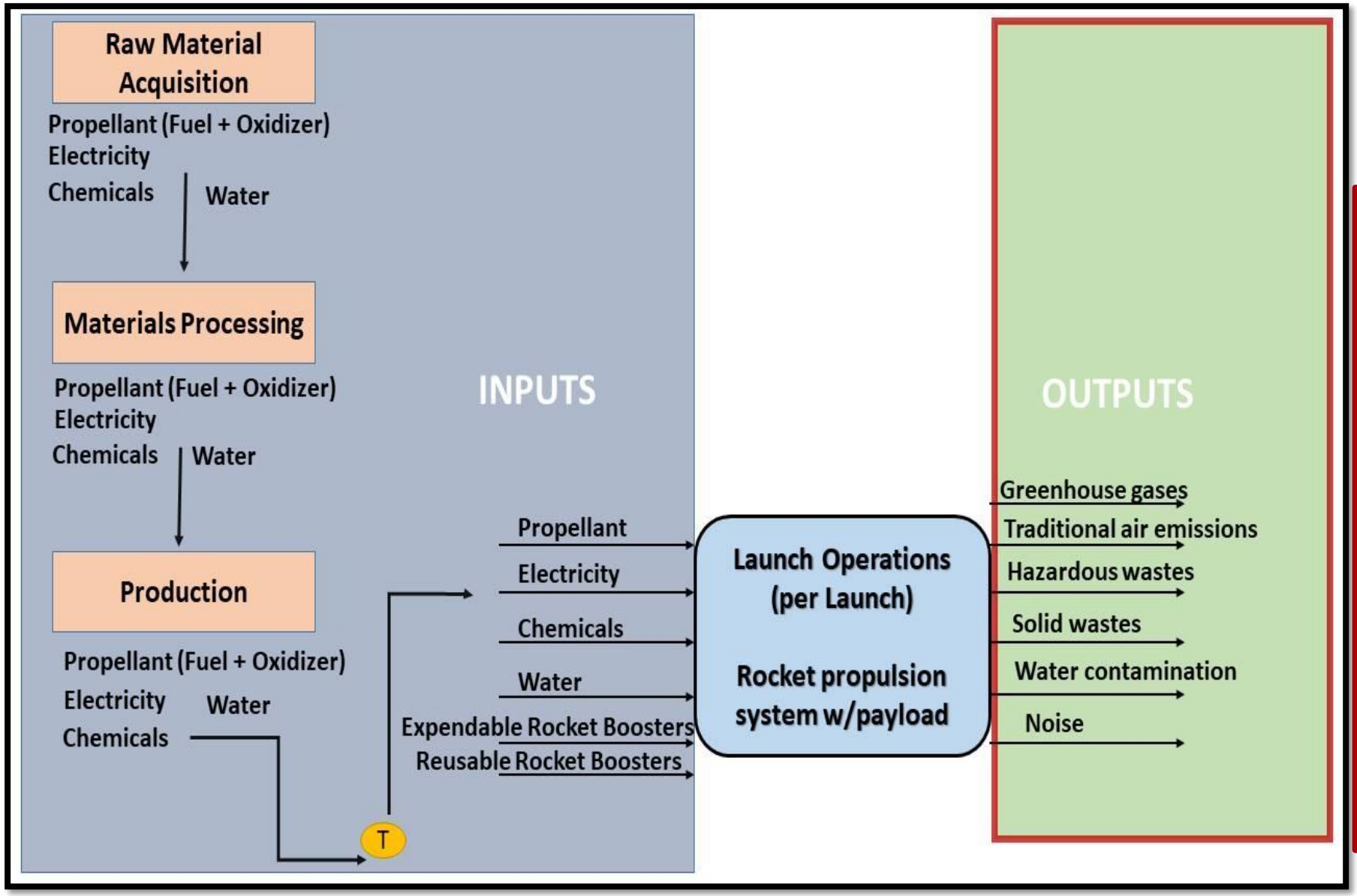


SYSTEMS ENGINEERING MODEL – SIMAPRO MODEL REUSABLE AND EXPENDABLE ROCKET BOOSTER





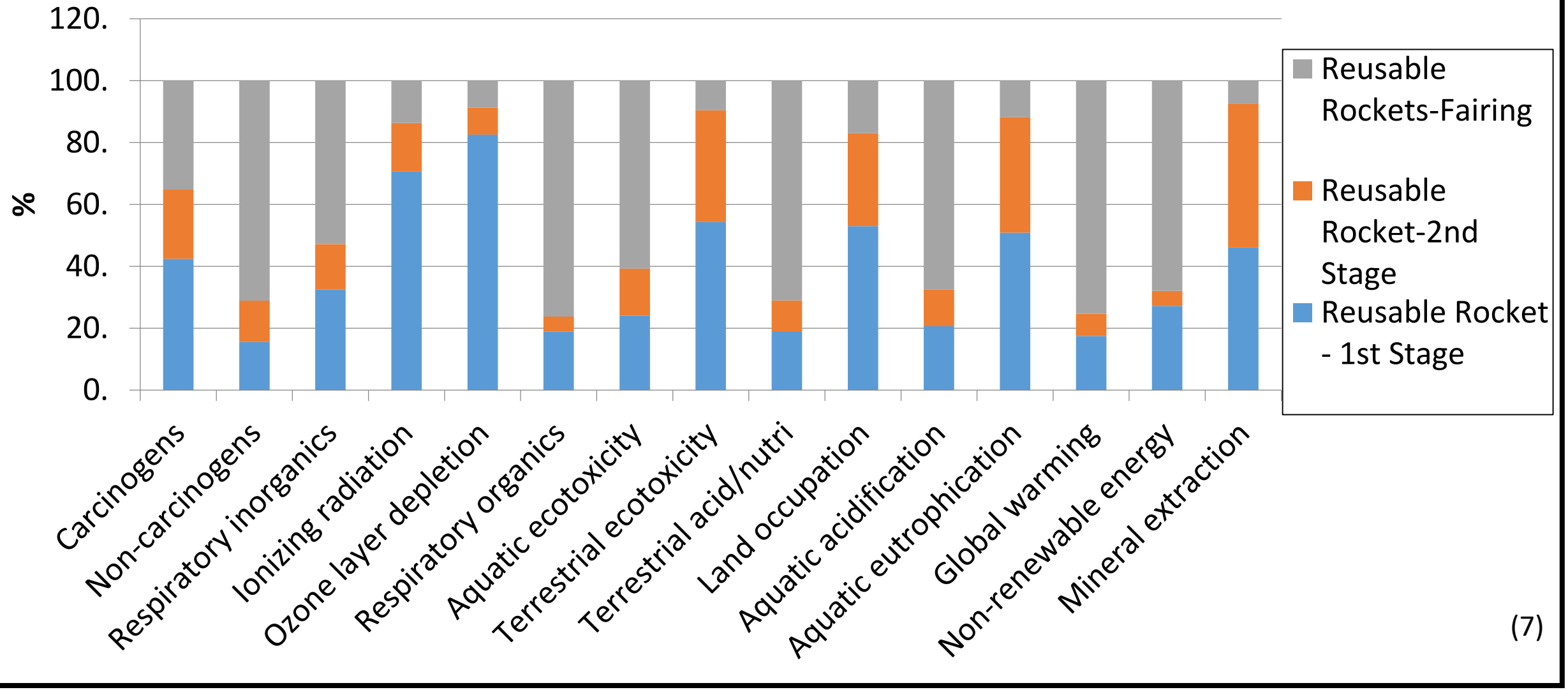
INVENTORY ANALYSIS OUTPUTS



SimaPro Outputs

- **Air Emissions**
  - Greenhouse gases
  - Traditional air emissions
- **Soil Emissions**
- **Water Emissions**

IMPACT ASSESSMENT
REUSABLE ROCKET BOOSTER WITH LANDING PROPELLANT
CHARACTERIZATION



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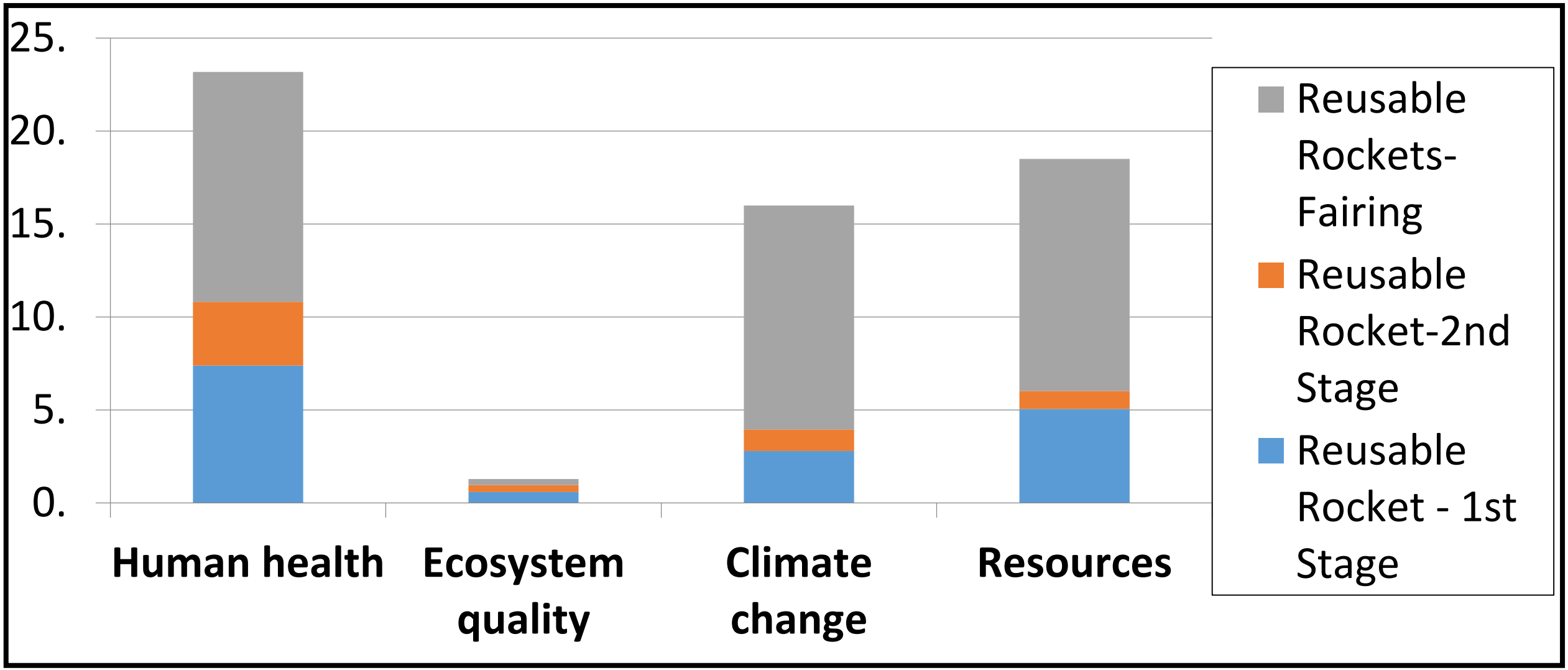
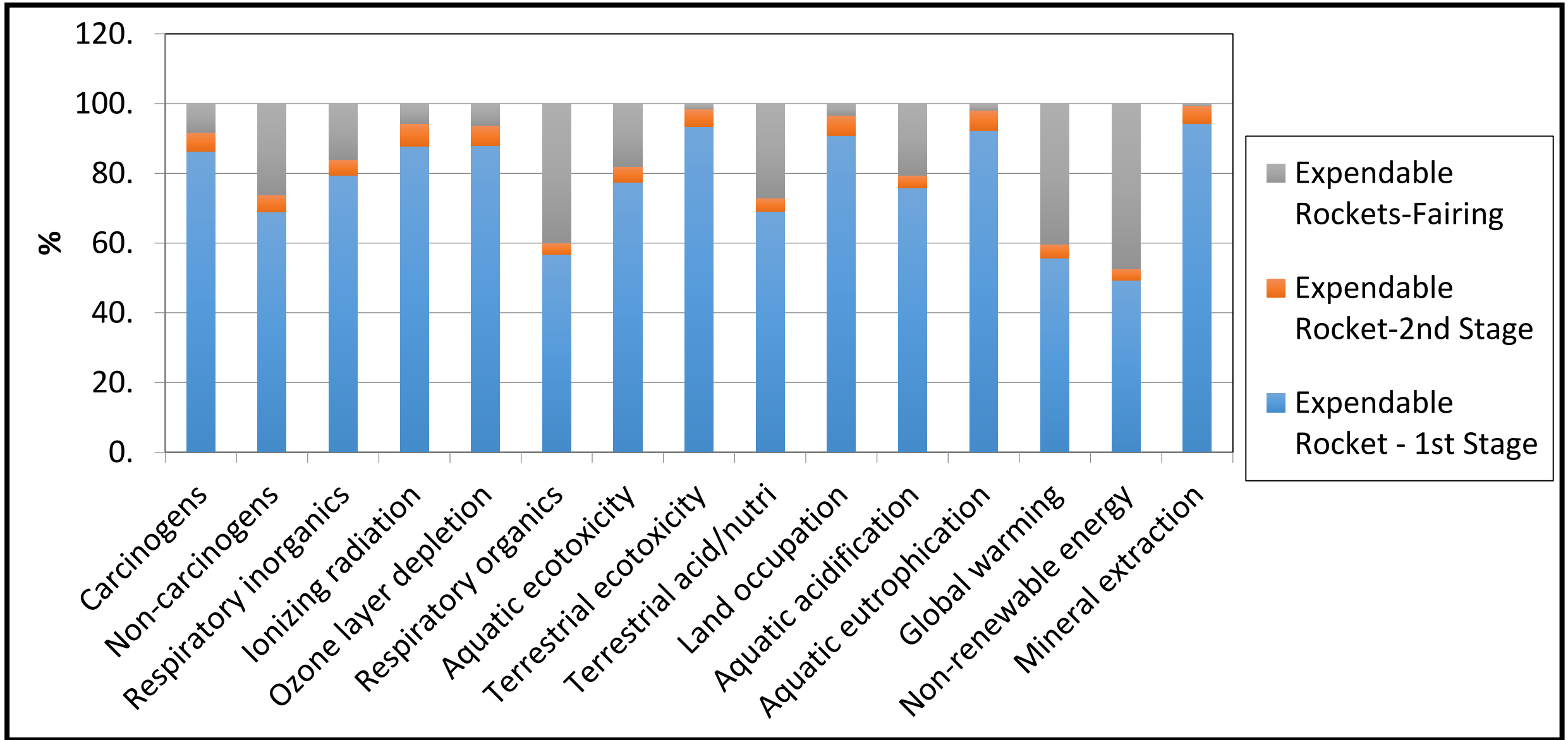
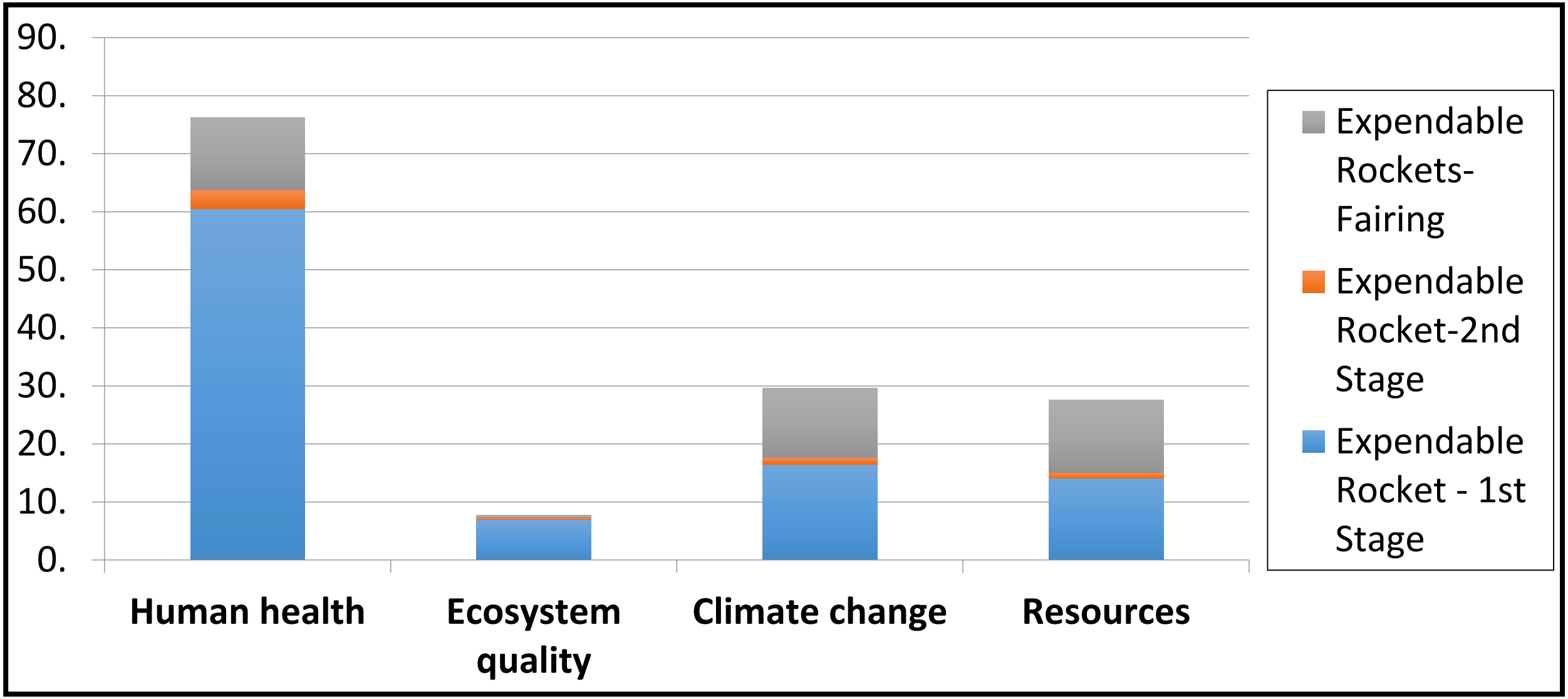
IMPACT ASSESSMENT
REUSABLE ROCKET BOOSTER WITH LANDING PROPELLANT
DAMAGE ASSESSMENT



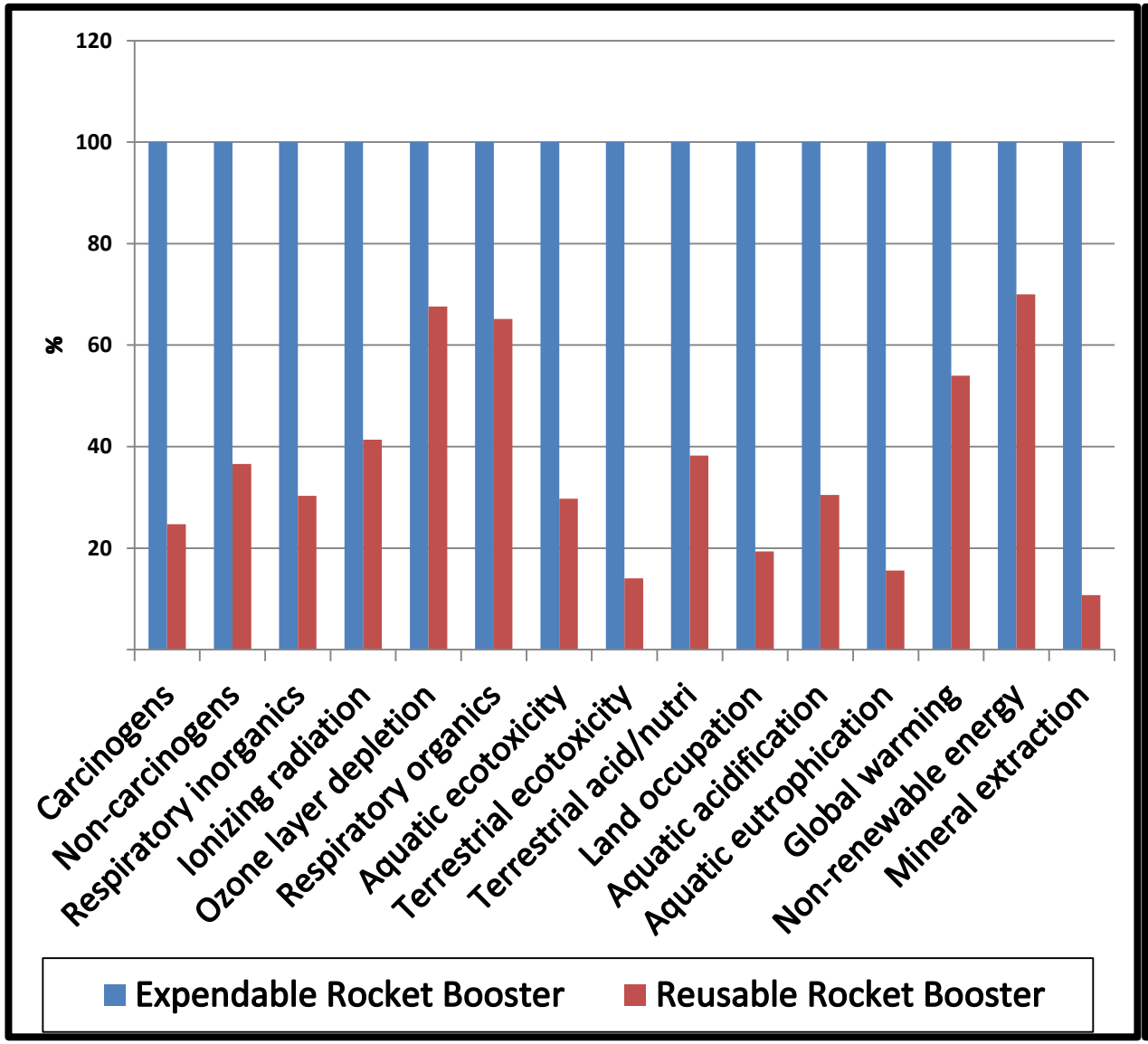
IMPACT ASSESSMENT
EXPENDABLE ROCKET BOOSTER - CHARACTERIZATION

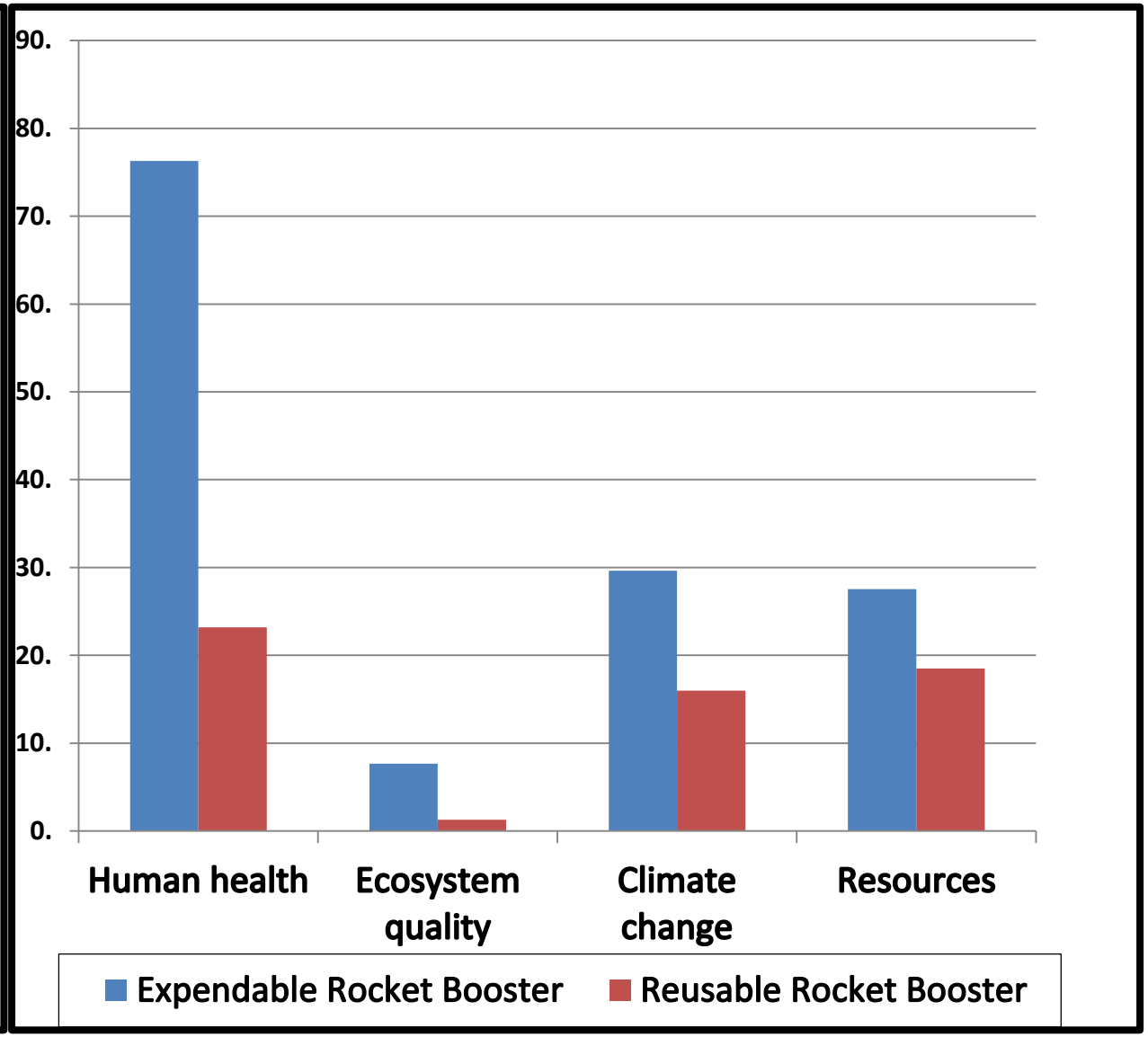


IMPACT ASSESSMENT
EXPENDABLE ROCKET BOOSTER – DAMAGE ASSESSMENT

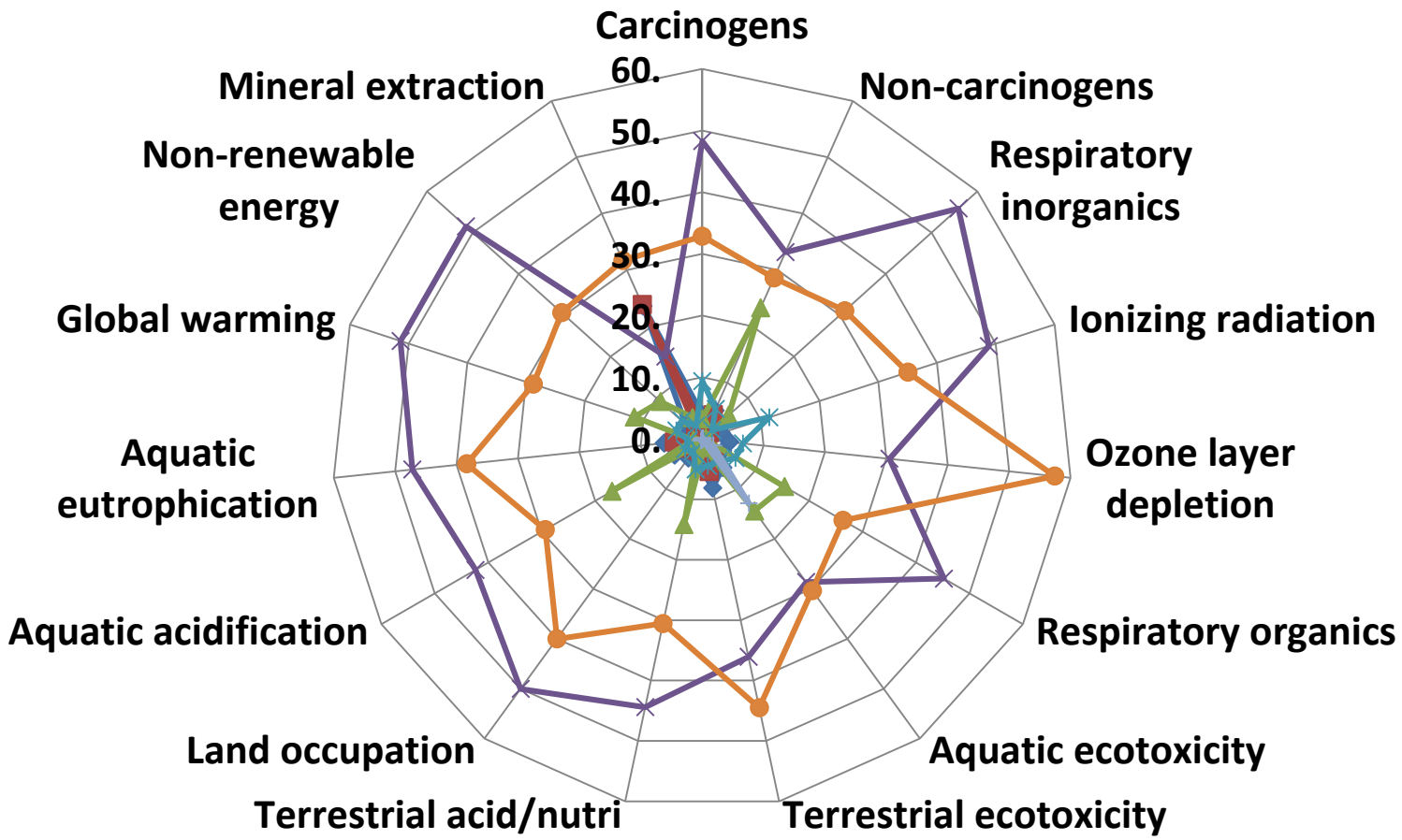


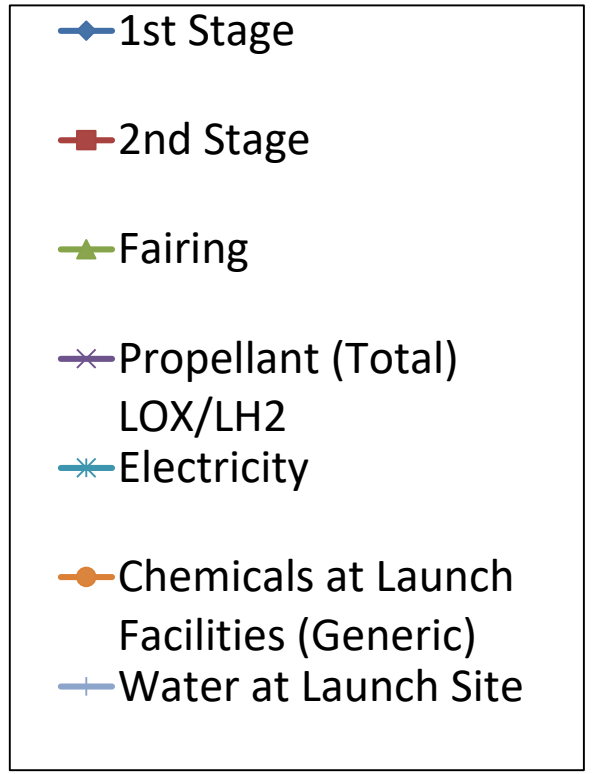
COMPARISON OF ROCKET BOOSTERS WITHOUT PROPELLANT CHARACTERIZATION & DAMAGE ASSESSMENT



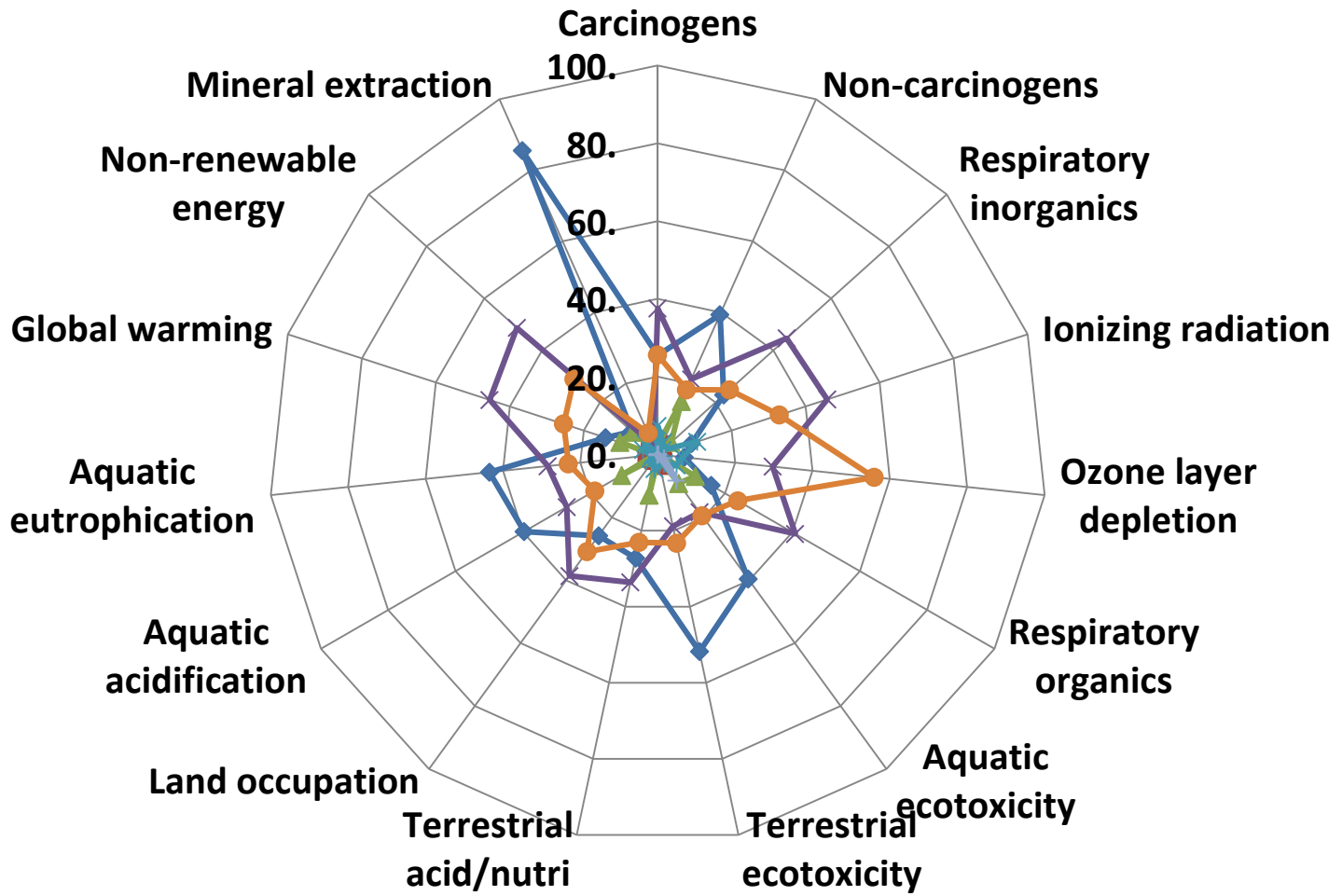


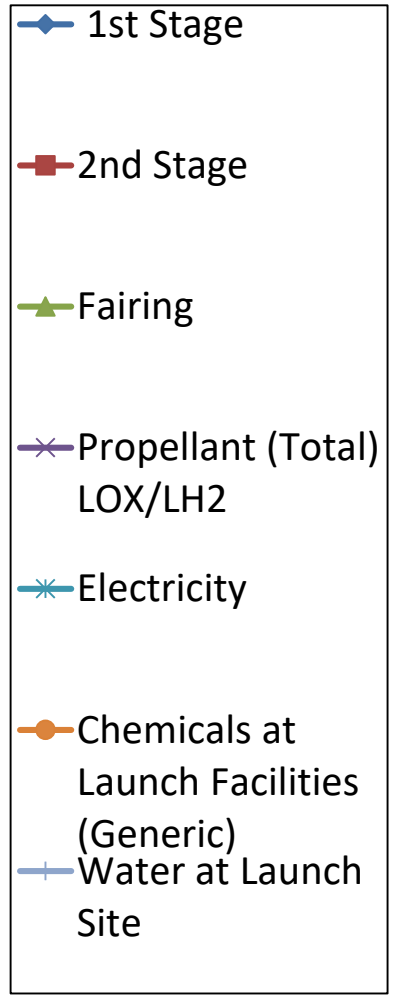
SPACE TRANSPORTATION ENVIRONMENTAL PROFILE FOR LAUNCH (STEP-L) REUSABLE ROCKET BOOSTER WITH LOx/LH_2 & ALL OTHER CONSUMABLES CHARACTERIZATION





SPACE TRANSPORTATION ENVIRONMENTAL PROFILE FOR LAUNCH (STEP-L) EXPENDABLE ROCKET BOOSTER WITH LOx/LH_2 & ALL OTHER CONSUMABLES CHARACTERIZATION





OPERATIONALIZING LCA RESULTS FOR CST ACTIVITIES
STEP-L DASHBOARD

- Tool for operators and planners
- System View of Environmental Domain
  - Systems Engineers
  - Environmental Professionals
  - Occupational Health Professionals
  - Other Decision Makers
- Inform NEPA process for CST activities
- Eco-Design or Environmental Sampling Options for Future Launchers

Interactive Demo

OPERATIONALIZING THE LCA OF THE CST LAUNCH ACTIVITIES
STEP-L DASHBOARD

STEP-L Dashboard

Launcher Parameters

Launcher Type
Expendable

Pad Operations

Test Firings	
2	(num.)

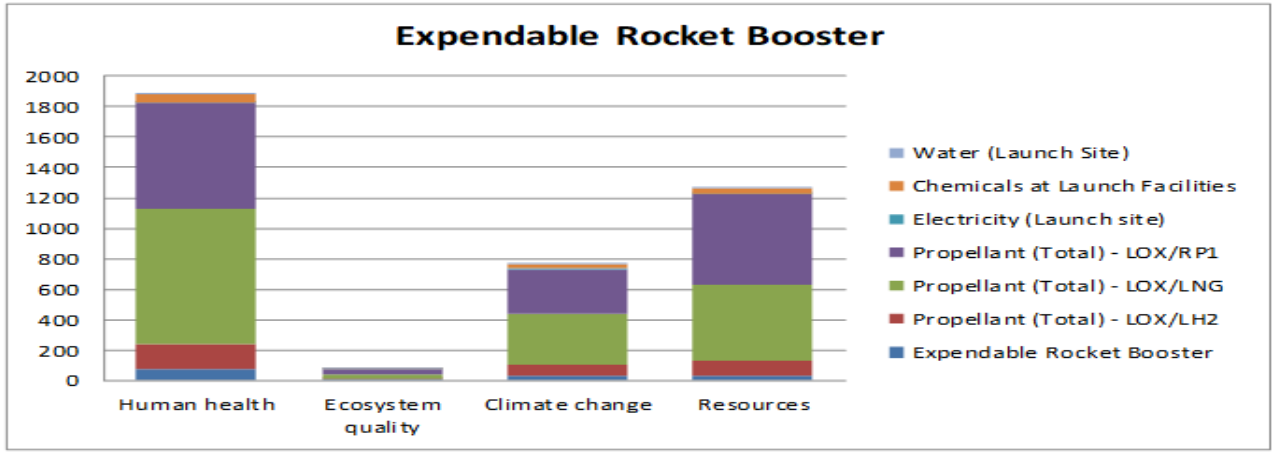
Electricity Use	
42,000	kWh (power plant)
224	Gen Hrs (Diesel)

Propellant Type		
LOX	1,884,696	kg
LH_2	29,500	kg
LNG	260,815	kg
RP1	345,229	kg

Water Use	
429,813	kg (personnel)
754,552	kg (deluge)

Chemicals		
Diesel	35,427	kg
Hvy Fuel Oil	681	kg
Lgt Fuel Oil	317	kg
Petrol	1,211	kg
Helium	39	kg
Hydrazine	13,635	kg
N2 (purge)	68,300	kg
N2 (2nd stg.)	295,968	kg
Isopropanol	74	kg

Reset Baseline Values:
Ctrl + d



Human Health	1891.1
Ecosystem	75.5
Climate Change	765.5
Resources	1269.9

OPERATIONALIZING THE LCA OF THE CST LAUNCH ACTIVITIES
STEP-L DASHBOARD

STEP-L Dashboard

Launcher Parameters

Launcher Type
Expendable

Pad Operations

Test Firings	
1	(num.)

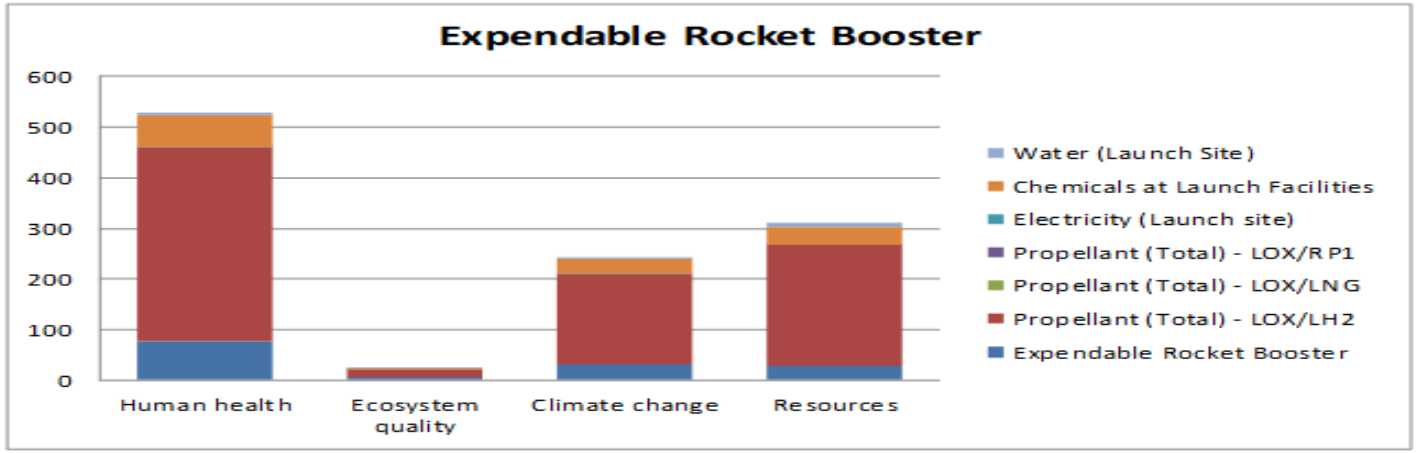
Electricity Use	
42,000	kWh (power plant)
224	Gen Hrs (Diesel)

Propellant Type		
LOX	594,354	kg
LH_2	100,273	kg
LNG	0	kg
RP1	0	kg

Water Use	
429,813	kg (personnel)
754,552	kg (deluge)

Chemicals		
Diesel	35,427	kg
Hvy Fuel Oil	681	kg
Lgt Fuel Oil	317	kg
Petrol	1,211	kg
Helium	39	kg
Hydrazine	13,635	kg
N2 (purge)	68,300	kg
N2 (2nd stg.)	295,968	kg
Isopropanol	74	kg

Reset Baseline Values:
Ctrl + d



Human Health	529.4
Ecosystem	22.0
Climate Change	243.7
Resources	310.5

STEP Dashboard | Step Data | Consumable Sensitivity | Sheet3

OPERATIONALIZING THE LCA OF THE CST LAUNCH ACTIVITIES

STEP-L DASHBOARD

STEP-L Dashboard

Launcher Parameters

Launcher Type
Reusable

Pad Operations

Test Firings	
1	(num.)

Electricity Use	
42,000	kWh (power plant)
224	Gen Hrs (Diesel)

Propellant Type			
	LOX	594,354	kg
	LH_2	100,273	kg
	LNG	0	kg
	RP1	0	kg

Water Use	
429,813	kg (personnel)
754,552	kg (deluge)

Chemicals		
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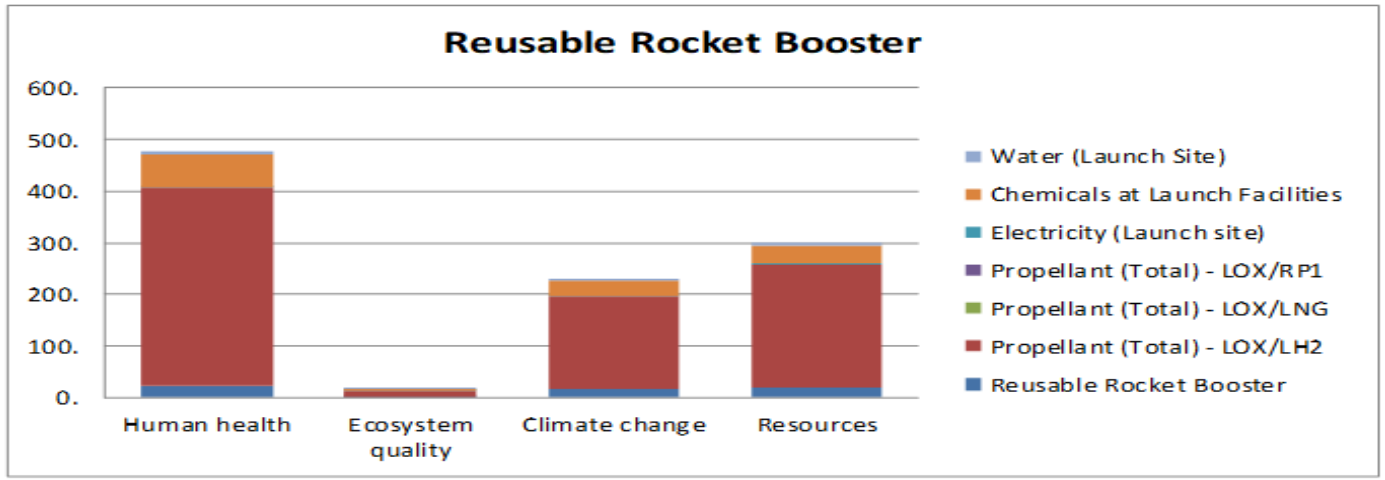
Reset Baseline Values:
Ctrl + d



Human Health	476.3
Ecosystem	15.6
Climate Change	230.1
Resources	301.5

SUMMARY

- Life Cycle Assessment (LCA) methodology, ISO 14040 and 14044, was used to evaluate **launch activities** for commercial space transportation in the United States
- **Reusability of 1st Stage** plays a significant role in reducing environmental burdens upstream in the raw acquisition, manufacturing, and even in the disposal costs
- As expected, environmental damage and burden associated with the use of a reusable rocket booster is less than the expendable rocket booster
  - Developed **STEP-L operational model**
- Results can be used to inform **eco-design, operational and disposal** decisions
- Rocket booster models can be easily refined for better fidelity of the LCA model

CONTACT INFORMATION

Shelia S. Neumann, Ph.D., P.E. (LtCol, USAF, retired)

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University of Texas at Arlington (graduate – May 2018)

240-210-0264 (cell phone)

Supervising Professor: Melanie Sattler, Ph.D., P.E.

*Published Dissertation in ProQuest

Shelia S. Neumann, Ph.D., P.E.

Location:

- Tampa, Florida

Leadership/Credentials:

- Licensed Professional Engineer (PE) in Texas
- TS/SCI; Recent with Full-Scope Polygraph - FBI (Feb 2017)
- DAWIA Program Management – Level 1; Test & Evaluation – Level II

Education:

- **PhD**: Environmental Engineering, UTA-Arlington (2018)
- **MS**: Mechanical Engineering, UTSA- San Antonio
- **MS**: Military Operational Art & Science, Air University
- **BS:** Chemical Engineering, Mississippi State University

Experience:

- DHS Intelligence (2013-2015) – Domestic Intel and GIS analysis/application
- FBI Intelligence (2009-2010) – WMD and Analytic Methodology
- USAF (1988-2008) Bioenvironmental Engineer
  - WMD/CBRN Readiness
  - Weapons System Test and Evaluation – Edwards AFB, CA
  - Intelligence – all-source analyst – authored 50 intel assessments
  - Superfund Program Manager ($83 million in contracts) – AFCEE
- US Army Corps of Engineers (1986-1988)– Water Treatment - Environmental Engineer at Dalecarlia Water Treatment Facility in DC

Current PhD Work: Environmental Life Cycle Assessment of Commercial Space Transportation Activities in the United States

- Life Cycle Assessment (LCA) methodology and Commercial Space Transportation in U.S./SimaPro tool
- Chaired/presented at NSF/UTA Workshop on Advanced Manufacturing of Aerospace (July 2017); Presented at NASA/ESA Workshop on International Energy and Environment at JPL (Oct 2016)

Selected Position Highlights

- **FBI WMD Proliferation Analysis and DIA Chemical Warfare Assessments**
  - Led 15 FBI all-source analysts for domestic WMD intelligence issues – developed analytic methods for analysis – Red Cell analysis and Futures analysis work – informed collection requirements, investigations, and source development; Instructed in analytic tradecraft using multi-media tools, hosted and led 2 methodology conferences for 100+ analysts on topics such as virtual world modeling and scenario development, behavioral science, analysis to operations ; co-authored FBI National Threat Assessment
  - Led 30 DIA all-source analysts for foreign CW intelligence issues – supported Iraqi Freedom – SOCOM & CENTCOM consumers – developed initial " WMD DOMINO " program methodology for target development and collection requirements initiated "National Counter Proliferation Center Follow the People" Program; revised CW MASINT requirements and re-ignited collection; briefed diverse consumers

- **412th Test Wing Health and Environmental Engineering Test & Evaluation**
  - Created a new developmental test discipline in 10 years, health and environment, for developmental aircraft test and evaluation at Edwards AFB, CA
  - Developed 20+ unique test plans for F-22, collected and analyzed various OSHA and EPA test data; executed test efforts with multi-disciplined personnel; authored 1st ever type H&E Engineering Testing technical reports, authored 4 technical test reports; created test model and simulation; and a SBIR for health and environmental test applications
  - Presented at NDIA /JSEM, AIHA , and AIAA conferences on test methodology and results

- **Water/Wastewater and Superfund Program Management**
  - Water treatment engineer at Dalecarlia Water Treatment Facility in DC, new chlorine alternatives
  - Water/wastewater consultant for USAF, developed wastewater characterization methodology and authored 5 technical reports to include hazardous waste, resolved 400 environmental field questions
  - Program manager of $83 million in Superfund clean-up contracts, streamlined environmental sampling and collaborated with regulators to close IRP sites or characterize with right amount of sampling

Strengths:

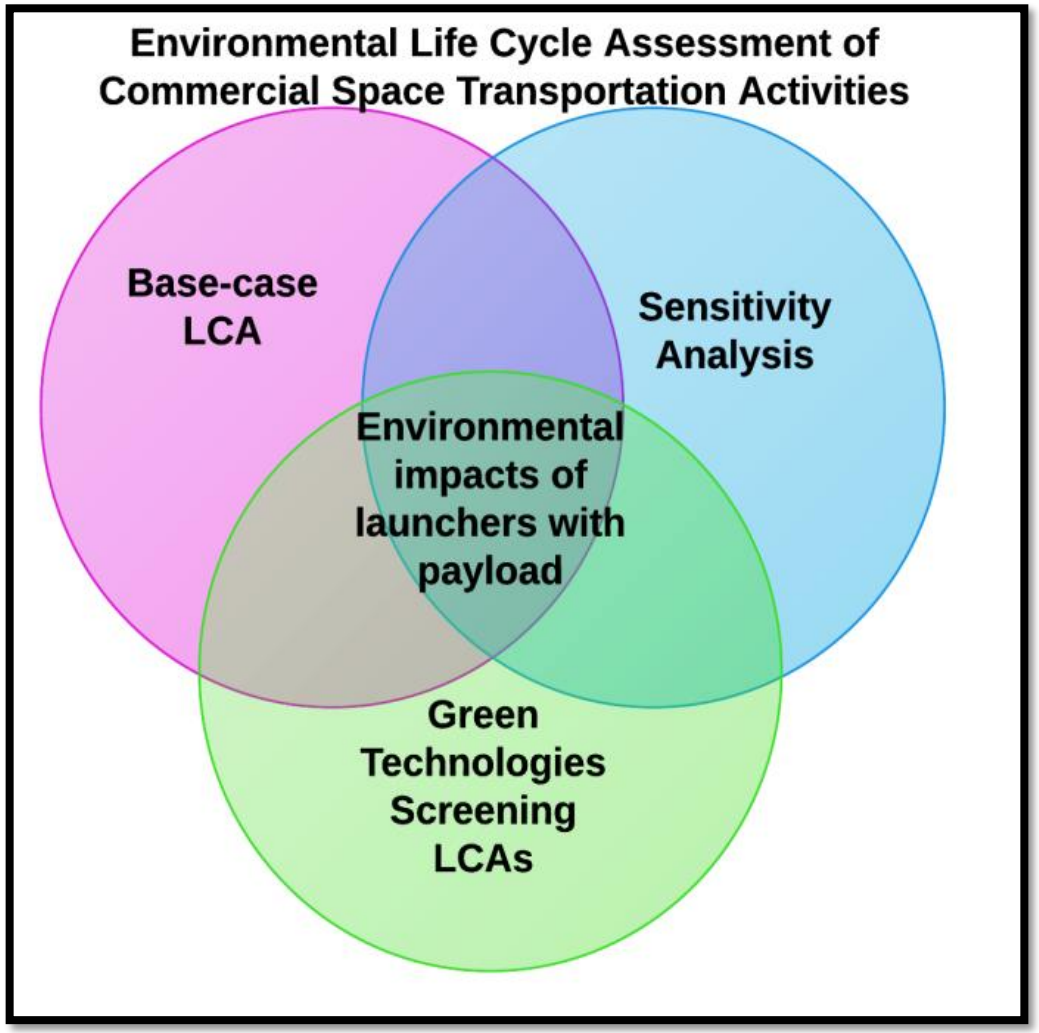
- Intelligence Analysis & WMD/CBRN
- Environmental methodology and test planning/execution; weapon system test
- LCA application to systems or services
- Lead diverse teams with a common goal – collaboration and teamwork
- Engineering Program Management
- Technical Writing
- Instructing/Wargaming-scenario and modeling development
- Integrate multiple analytic tools to resolve intelligence or engineering issues

DISSERTATION OVERALL GOAL

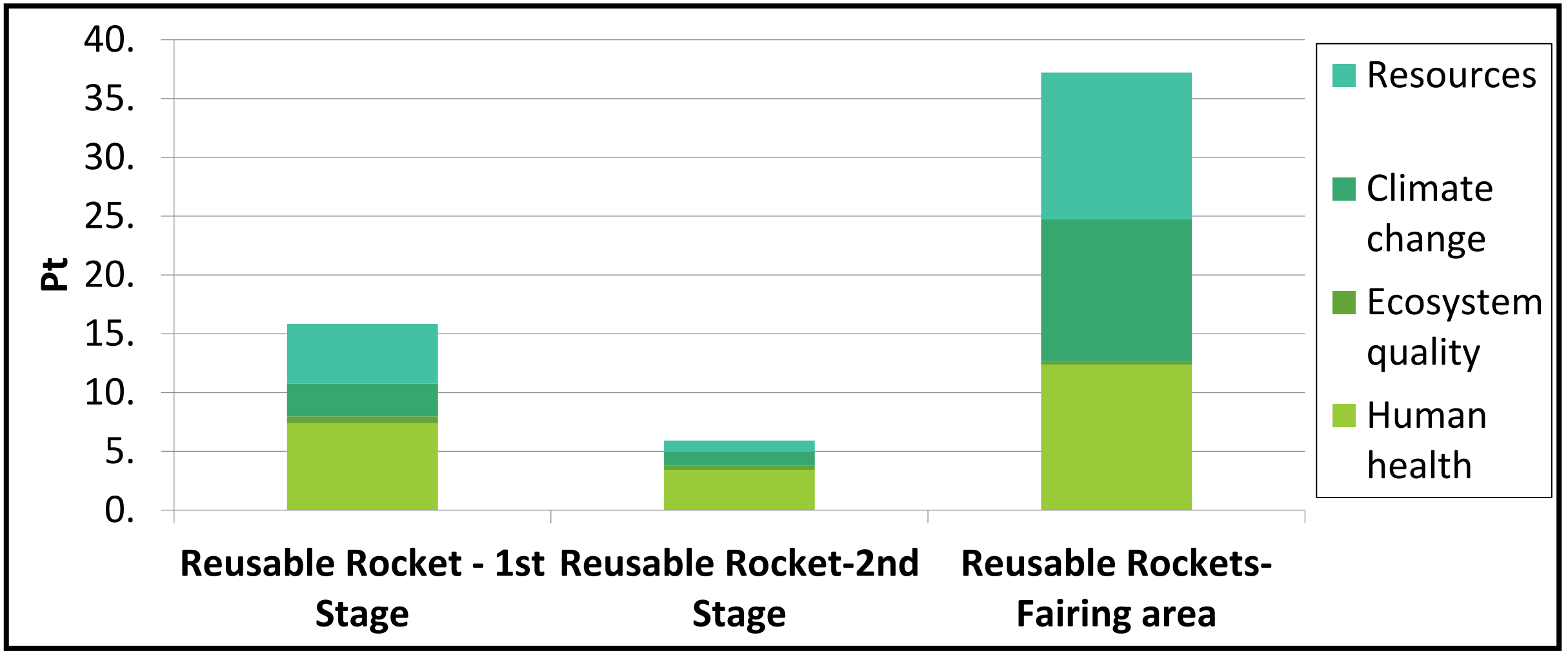
Develop a Framework and Methodology to Understand the Environmental Burdens and Impacts from CST Activities in the United States

DISSERTATION OBJECTIVES

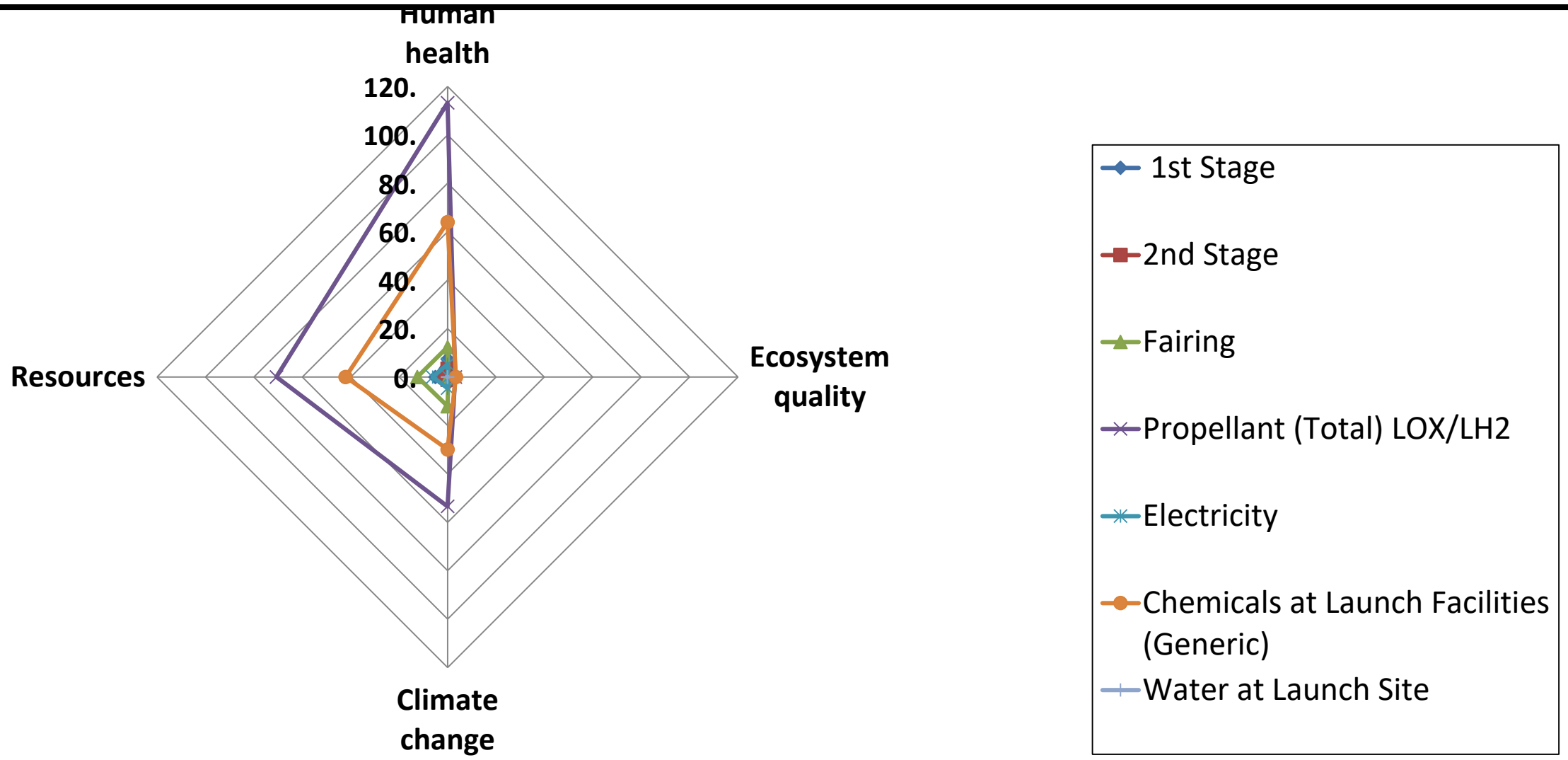
- **Objective #1:** Conduct a base-case LCA for commercial space transportation activities in the United States
- **Objective #2:** Identify range of impacts due to uncertainty in model inputs (sensitivity analysis)
- **Objective #3:** Conduct screening LCAs incorporating "green technologies" using base-case LCA to identify potential strategies for reducing environmental impacts in U.S. CST activities



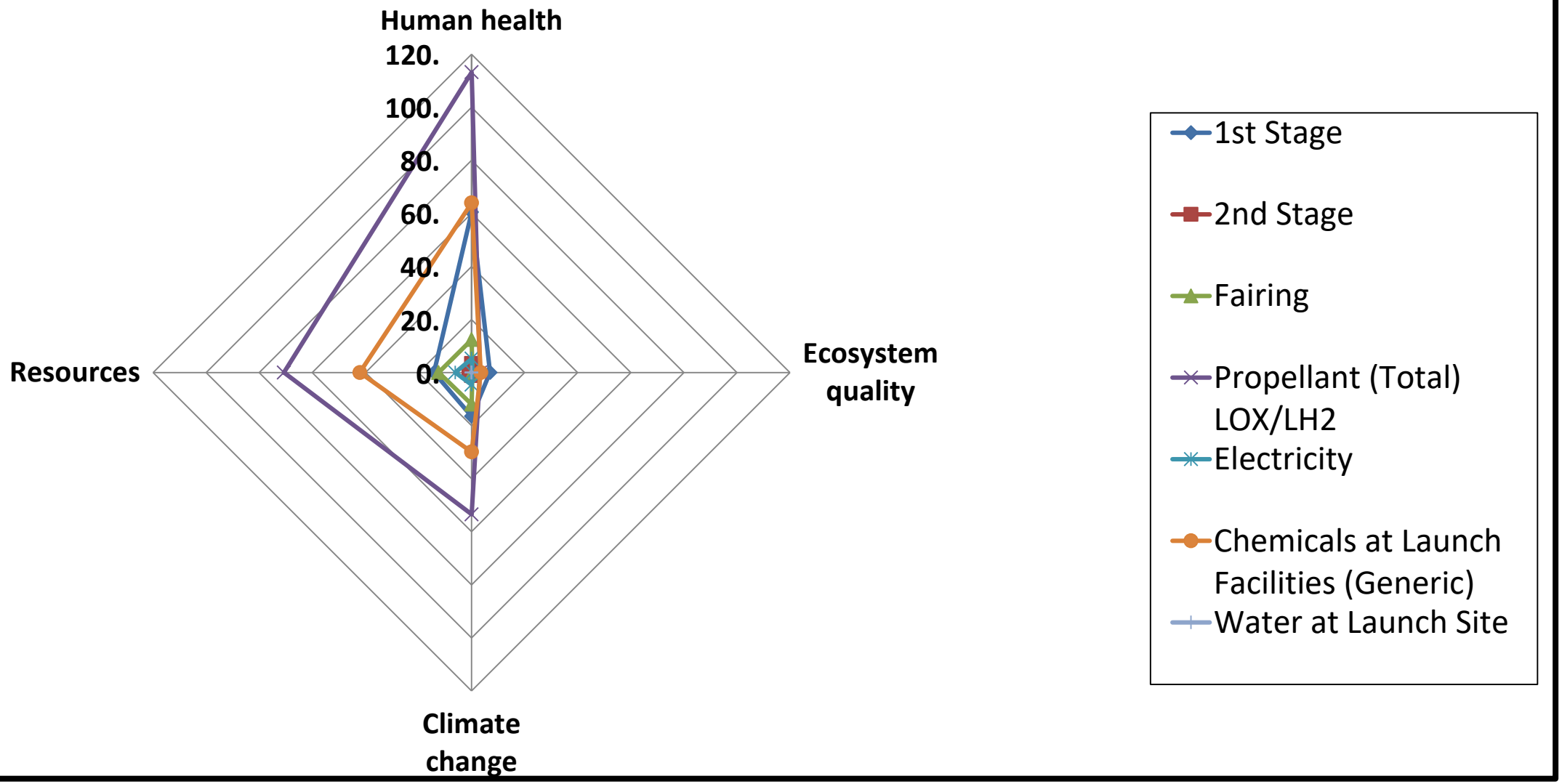
IMPACT ASSESSMENT
REUSABLE ROCKET BOOSTER WITH LANDING PROPELLANT
DAMAGE ASSESSMENT SINGLE SCORE



SPACE TRANSPORTATION ENVIRONMENTAL PROFILE FOR LAUNCH (STEP-L)
REUSABLE ROCKET BOOSTER WITH LOx/LH_2 & ALL OTHER CONSUMABLES
DAMAGE ASSESSMENT



SPACE TRANSPORTATION ENVIRONMENTAL PROFILE FOR LAUNCH (STEP-L) EXPENDABLE ROCKET BOOSTER WITH LOx/LH_2 & ALL OTHER CONSUMABLES DAMAGE ASSESSMENT



References

- (1) SpaceX Orbital Communication image: http://www.spacex.com/gallery/orbcomm-2-mission-december-2015; accessed 9/16.
- (2) FAA, 2016 and 2018, "FAA Commercial Space Operational Data," http://www.faa.gov/data_research/commercial_space_data/, accessed 10/16, 3/18, and 9/18.
- (3) FAA, 2014, "U.S. Space Transportation Industry," http://www.faa.gov/about/office_org/headquarters_offices/ast/industry/media/Map_US_spaceports.pdf, accessed 9/15.
- (4) International Organization for Standardization (ISO) 14040, 2006, https://www.iso.org/standard/37456.html, accessed 7/2015.
- (5) Life cycle inputs and outputs image, https://sftool.gov/plan/400/life-cycle-assessment-lca-overview, accessed 9/16.
- (6) Generic Launch Campaign Activities slide generated from multiple graphics found in google and yahoo searches for transportation, NASA and SpaceX, accessed 1/18.
- (7) SimaPro LCA Software, Version 8.2.3, used for results for Characterization and Damage Assessment