LaunchU Business-Oriented Benefits Analysis

Prepared for Aerospace Corporation

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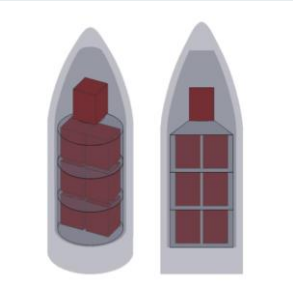
Objective and Methodology

Developing business-oriented benefits of LaunchU from smallsat operator and small launch vehicle perspective

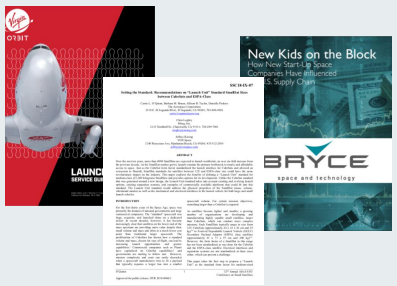
LaunchU Attributes



LaunchU Potential Benefits

- ❑ Reduced integration costs
- ❑ Streamlined pre-launch processes
- ❑ Enables satellite operators to swap launch vehicles
- ❑ Enables launch providers to swap satellites
- ❑ Reduces manufacturing costs
- ❑ Reduces manufacturing time

Interviewed 8 industry experts and potential users



Reviewed Industry and academic literature

Assessed Risks and Barriers

Assessed potential benefits

Identified Key business-oriented benefits

Developed key factors for each business sector

Assessed Hypothesized Benefits

Potential Benefit	Commercial Smallsat Operators and Manufacturers	Commercial Launch Provider	Government
Reduced integration costs		✓	✓
Streamlined pre-launch processes	✓	✓	✓
Enables satellite operators to swap launch vehicles	✓	✓	✓
Enables launch providers to swap satellites	✓	✓	✓
Reduces manufacturing cost	✓		✓
Reduces manufacturing time	✓		✓

Interviews revealed additional benefits for **entrepreneurs** seeking to launch smallsats

Assessment Methodology

Interviewed representatives at 8 organizations

Conducted industry, academic literature review

Interviews provided valuable, actionable insights into benefits, risks, and barriers

Literature review confirmed interview findings and helped fill quantitative gaps

Assessed Key Benefits for Each User Group

Benefit

- Identifies potential benefit
- Describes potential benefit and mechanism for achieving it

Confirmed through Bryce assessment

- ✓ Assessment of likelihood of LaunchU producing hypothesized benefit
- ✓ Assessment of value of benefit for relevant user group
- ✓ Assessment of likelihood that relevant user groups would adopt LaunchU to achieve benefit

Risks and Barriers

- Identified key risks and barriers likely to impede user group's ***adoption*** of LaunchU
- Identified key risks and barriers likely to impede user group's ability to ***capture benefits*** even if they do adopt LaunchU
- Includes risks and barriers stemming from market conditions, technical specifications, formal policy, and current practice

Commercial smallsat manufacturer and operator benefits

Launch provider benefits

Government benefits

Entrepreneur benefits

Key findings

Smallsat Operator and Manufacturer Benefits

Potential Benefit	Commercial Smallsat Operators / Manufacturers
Reduced integration costs	
Streamlined pre-launch processes	✓
Enables satellite operators to swap launch vehicles	✓
Enables launch providers to swap satellites	✓
Reduces manufacturing cost	✓
Reduces manufacturing time	✓

- ✓ Research confirmed all hypothesized benefits
- ✓ Experts identified ability to swap launch vehicles and reduced manufacturing time and costs as the **key benefits** for commercial operators
- ✓ Streamlined pre-launch procedures and ability to swap satellites, while benefits for satellite manufacturers and operators, were not identified as key benefits
- ✓ Experts identified additional specific benefits for **entrepreneurs**, addressed in its own section

LaunchU Standard Likely to Reduce Manufacturing Cost and Time

Benefit

- LaunchU standard would enable the use of common hardware and components
- Adoption of common hardware and components reduces manufacturing costs through economies of scale
- Production at scale also accelerates manufacturing timelines

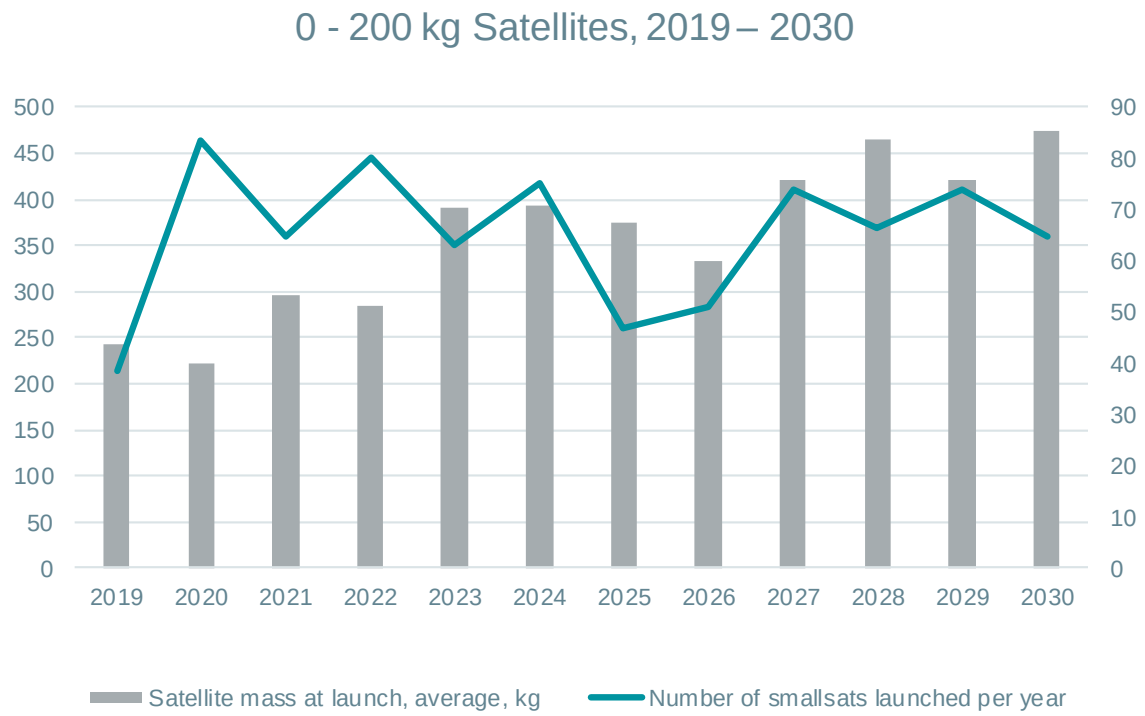
Confirmed through Bryce assessment

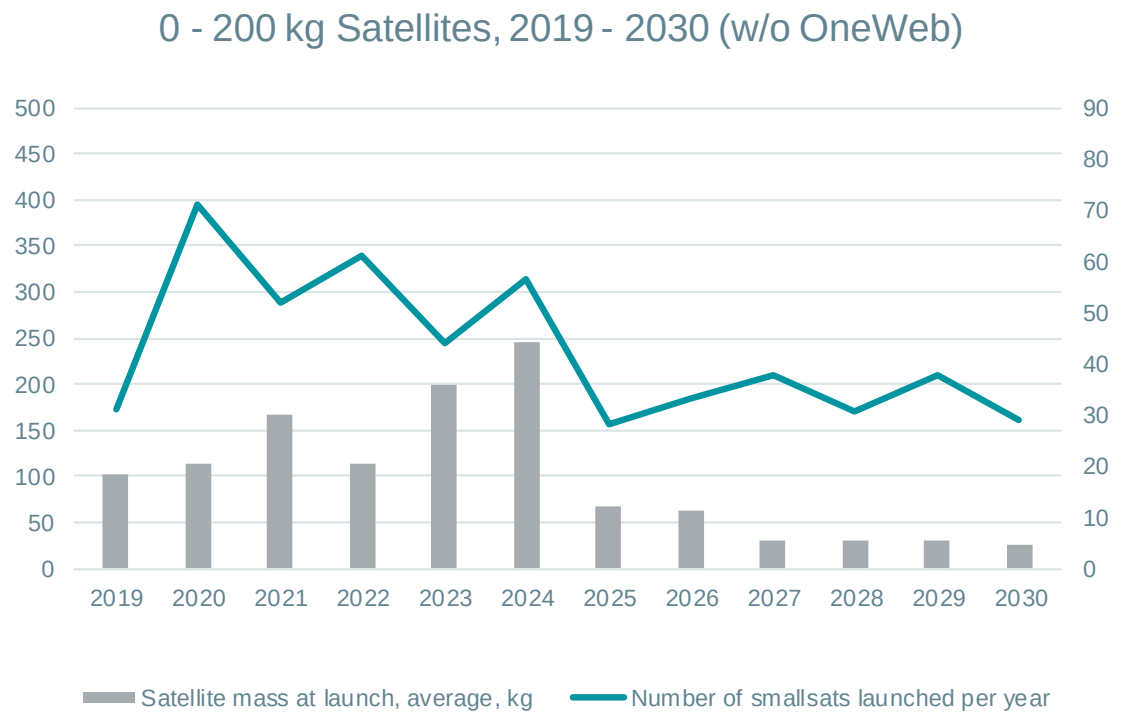
- ✓ Expert consensus that LaunchU would enable use of mass produced hardware and components (less applicable for highly specialized missions)
- ✓ Expert consensus that there are cost and time benefits to using mass produced hardware and components (enables more suppliers to enter market, creates more competition)
- ✓ ISS and CubeSat experience demonstrate that standardization can increase competition and reduce manufacturing time and costs
  - ISS standardization of power and Ethernet requirements has led to increased supplier base and ability to purchase COTS products
  - SSTL has stated, "Not so much the CubeSat itself that has driven this explosion in nanosatellite but rather the standardized (P-POD/QuadPack) launch interface"
- ✓ Companies have demonstrated willingness to adopt this practice: companies building mega-constellations are pursuing mass production (e.g. OneWeb)

To capture these benefits LaunchU must meet operator needs and account for risks and uncertainties

Average Size of Announced Satellites 0 – 200 kg, 2019 – 2030

Experts say market is moving toward larger satellites (~100kg) for more capability





Notes:

- Includes publicly announced systems utilizing smallsats 0 – 200 kg and projections for some categories based on open source data (e.g., replenishment rates for commercial CubeSat constellations such as Planet and Spire, USG experimental smallsat constellations, and academic and educational CubeSats)
- Actual annual deployment rates beyond 2019 – 2020 may vary; estimates based on published deployment plans, historical launch rates, and known launch provider throughput projections

Capturing Manufacturing Cost and Time Benefits

To capture manufacturing time and cost benefits the LaunchU standard must….

Address 3 key operator needs

1. Must fit broad market size requirements – more uses require more power and larger size
2. Must fit manufacturer's specific business case
3. Must enable multiple hardware and component suppliers/manufacturers to meet requirements

Account for risk and uncertainties

Risks include:

- Launch availability bottlenecks
- Insufficient market size (experts estimate about 100 LaunchU smallsats must be built each year to create economies of scale)
- Established manufacturers resist change – existing industry players may have incentives to keep barriers to entry high

LaunchU Standard Enables Satellite Operators to Swap Launch Providers

Benefit

- LaunchU standards makes satellites and launch vehicles more interchangeable
- Frees satellite operator from being tied to one launch provider, may switch to another launch provider if launch is delayed or payload is ready ahead of schedule
- Enables reliable launch on demand
- Allows satellite operators to get to satellites to orbit faster (when possible)

Confirmed through Bryce assessment

- ✓ Experts agreed that LaunchU standards would make satellites and launch vehicles more interchangeable
- ✓ Experts agreed that satellite operators would be likely to adopt a standard that increased launch flexibility
- ✓ Experts agreed that satellite operators would see value in ability to swap launch providers
- ✓ Satellite operators have demonstrated willingness to swap CubeSats whether they are ridesharing to orbit or deployed from ISS
- ✓ Swap-ability highlighted as a benefit of standardization by satellite operator: “One of the beauties of the CubeSat standard is that there can be a last-minute switch: from the launch vehicle’s perspective, it doesn’t matter what’s inside the deployer” (Mark Safyan, Planet)

Capturing these benefits faces risks and uncertainties regarding logistics and satellite operator/launch provider expectations

Capturing Benefits from Ability to Swap Launch Vehicles

Capturing benefits from swapping launch vehicles faces risks and uncertainties

- **There may not be a sufficient stockpile of satellites to enable launch vehicle swapping**
  - Swapping satellites between launch vehicles requires a sufficient stockpile of satellites that fit similar mission profiles (orbit/inclination, separation requirements)
  - Without a stockpile, swapping capability is limited and unreliable
- **Satellite operator operational needs and expectations may impede swapping launch vehicles**
  - Experience swapping CubeSats has demonstrated that satellite operator flexibility with launch mission profiles is useful in swapping launch vehicles
  - Larger, LaunchU sized spacecraft tend to have more complex missions than CubeSats
  - These missions provide more value to operators, but may reduce launch flexibility
  - Additionally, manufacturing satellites that can meet more complex missions is more expensive than manufacturing CubeSats; increased investment in manufacturing may further increase satellite operator expectations and requirements for launch, and reduce flexibility
- **It is unclear whether satellite operators will be willing to pay a premium for launch flexibility (buying a last minute airline ticket), or if they will expect a discount for their flexibility (flying standby)**
  - Unaligned launch provider and satellite operator expectations could impede market
  - Not a binary answer – both options may exist simultaneously

Key Benefits for Satellite Manufacturers and Operators

Planned smallsats near LaunchU size provide unique opportunity for LaunchU to shape the market

- There are proven cost and time benefits to adopting a standardized satellite form factor, like LaunchU
- Standardizing form factor and reducing customization provides economies of scale for both manufacturers and operators
- Standardizing form factor and reducing customization increases competition, expanding customer markets for satellite manufacturers and increasing supply chain options for satellite operators

Commercial smallsat manufacturer and operator benefits

Launch provider benefits

Government benefits

Entrepreneur benefits

Key findings

Commercial Launch Provider Benefits

Potential Benefit	Commercial Launch Provider
Reduced integration costs	✓
Streamlined pre-launch processes	✓
Enables satellite operators to swap launch vehicles	✓
Enables launch providers to swap satellites	✓
Reduces manufacturing cost	
Reduces manufacturing time	

- ✓ Research confirmed all hypothesized benefits
- ✓ Reduced integration costs and streamlined pre-launch procedures and ability to swap satellites were identified as **key benefits** for commercial launch providers

LaunchU Can Reduce Integration Costs and Streamline Pre-launch Processing

Benefit

- LaunchU establishes common hardware and interfaces
- Leads to standardized engineering analysis products
- Reduces lead times and costs for hardware and interfaces analyses
- Reduces integration costs and streamlines pre-launch processing

Confirmed through Bryce assessment

- ✓ Time spent completing engineering analysis is a substantial contributor to integration and processing timelines
- ✓ Standardization allows integration lead times to be measured in days/weeks rather than months
- ✓ Experts agreed that establishing a standard shape and standard analysis would reduce integration and processing times (allowing "plug and play" launch)
  - Analysis should demonstrate that any payload meeting the standard could survive the worst case scenario
  - Standardized bus allows reuse of engineering products and saves the most time
  - Reduces mission-specific engineering and procedures
- ✓ LaunchU currently listed in at least one launch vehicle User Guide (Firefly Alpha)

Current Processing Times

- Non-standardized smallsats can take 30 - 60 days to integrate
- CubeSats, which are standardized, can be integrated in as little as 3 hours

Launch industry reports it is not particular about the specific standard as long as it is comprehensive

Positioning LaunchU to Become the Accepted Standard

Experts identified key elements that a useful, widely accepted standard would address

- Mass
- Volume
- Connectors
- Power
- Environments the satellite can withstand

LaunchU addresses all expert identified elements

Next step is to continue efforts to ensure launch providers are aware that LaunchU addresses these elements

Capturing Benefits from Lower Integration Costs and Streamlined Pre-Launch Process

To capture benefits of lower cost integration and streamlined pre-launch processes requires accounting for risk and uncertainties

- Potential cost and processing time benefits may be negated by manufacturers that customize around the standard, which has happened with ESPA-class payloads
- Efficiencies are reduced if the standard does not meet all expert identified elements
- Other groups are working launch guides and potential standards; LaunchU must keep abreast of these efforts to avoid competing with them

LaunchU Standard Enables Launch Providers to Swap Satellites

Benefit

- Standardization enables easier swapping of satellites
- Within existing launch operating model, allows launch providers to easily replace payloads that drop out
- LaunchU could enable new launch provider business models

Confirmed through Bryce assessment

- ✓ Lack of standardization is a current challenge for coordinating smallsat launches
  - SSO-A mission is recent example of this challenge. SSO-A mission started with 97 different payloads. It experienced difficulty designing a final solution due to drop outs. Problem was compounded when satellites that dropped out had custom interfaces – drove up pricing, out of competitive range
- ✓ CubeSat standardization enables swaps on ISS launches, experts report swaps are common
- ✓ Experts agree LaunchU standard could increase ability for launch providers to swap satellites

Experts believe LaunchU standard could create potential for new launch operating models

LaunchU Could Lead to New Launch Provider Business Models

- 40+ companies have announced new small launch vehicles
- 24 companies have small launch vehicles in a material phase of development
- Unlikely that the market will support all of these small launch vehicles
- Small launch companies are **seeking to differentiate their product** offerings to capture market share
  - Offering integrated end-to-end satellite solutions (e.g. Firefly + York integrated partnership, Rocket Lab Photon upper stage solution)
  - Increasing planned launch capacity in attempt to capture more of the market (Firefly and Virgin)
- **LaunchU could enable new business models that would provide the differentiation these companies seek**
  - Develop a "common berth." Package satellites for the berth with standard harness and form factors, plug in and ready for launch
  - Launch to SSO at regular intervals and allow payloads to just show up
  - Specifically target and develop capabilities to support very last minute rides

Capturing Benefits from Ability to Swap Satellites

Capturing benefits from swapping satellites faces risks and uncertainties

- **There may not be a sufficient stockpile of satellites to enable satellite swapping**
  - Swapping satellites on a launch vehicle requires a sufficient stockpile to satellites that fit similar mission profiles (orbit/inclination, separation requirements) to enable swapping
  - Without a stockpile, swapping capability is limited and unreliable
- **Satellite operator operational needs and expectations may impede swapping**
  - Experience swapping CubeSats has demonstrated that satellite operator flexibility with launch mission profiles is useful in swapping satellites
  - Larger, LaunchU sized spacecraft (~100 kg) tend to have more complex missions and less launch flexibility than CubeSats
  - Manufacturing satellites that can meet more complex missions is more expensive that manufacturing CubeSats; increased investment in manufacturing may further increase satellite operator expectations and requirements for launch and reduce flexibility
- **It is unclear whether satellite operators will be willing to pay a premium for launch flexibility (buying a last minute airline ticket), or if they will expect a discount for their flexibility (flying standby)**
  - Unaligned launch provider and satellite operator expectations could impede market
  - Not a binary answer – both options may exist

Key Benefits for Launch Providers

LaunchU benefits launch providers and enables them to better serve customers

- There are proven cost and time benefits to adopting a standardized satellite form factor, like LaunchU
- LaunchU can greatly simplify launch processing by significantly decreasing required engineering analyses
- Streamlined launch processing reduces burden on launch providers and allows them to offer customers faster access to space
- LaunchU allows launch providers to open up more launch opportunities through multi-manifesting and ability to replace payloads if one drops out (more efficient for both launch provider and satellite operators)

"Launch needs to get to the point where it is commoditized and the only way to do that is through standards" – Chris Loghry, Moog

Commercial smallsat manufacturer and operator benefits

Launch provider benefits

Government benefits

Entrepreneur benefits

Key findings

Government Benefits

Potential Benefit	Government
Reduced integration costs	✓
Streamlined pre-launch processes	✓
Enables satellite operators to swap launch vehicles	✓
Enables launch providers to swap satellites	✓
Reduces manufacturing cost	✓
Reduces manufacturing time	✓

- ✓ Research identified key mission assurance benefits for government operators
- ✓ Experts identified reduced manufacturing time, ability to swap satellites, ability to swap launch vehicles, and streamlined pre-launch processes as the key benefits that enable mission assurance
- ✓ Reduced manufacturing costs and reduced integration costs, while benefits for the government, were not identified as key benefits

LaunchU Could Enable Responsive Space Missions

Benefit

- Reducing manufacturing time increases government ability to stockpile satellites for responsive missions
- Standardization will likely increase number of suppliers, benefitting government mission assurance
- Ability to swap satellites and launch vehicles gives government more avenues to meet short-notice launch requirements, a key requirement of enabling responsive space

Confirmed through Bryce assessment

- ✓ Resilience is an important element in planned government smallsat missions (e.g. Blackjack, Casino, etc.)
- ✓ Standardization could enable bulk launch and satellite buys for many customers, including government
- ✓ Government has demonstrated willingness to purchase bulk launches and bulk satellites, but lack of standardization has not enabled satellite trades across these purchases
- ✓ Standardization would create new opportunities to trade satellites across launches and launch providers

Government as a leading customer could catalyze the LaunchU market

Government Customers Could Catalyze the LaunchU Market

- Government is in a unique position to spark conversation about and generate manufacturer interest in LaunchU
- Government seeks to launch a significant number of smallsats for responsive space missions
- Could enable larger satellites to be used in responsive space missions
- A government commitment to meeting LaunchU form factor for a significant portion of those satellites would likely drive interest in LaunchU from both satellite manufacturers and launch operators

Capturing Benefits for Government

Capturing benefits for government faces risks and uncertainties

- Government mission developers not accustomed to thinking about shape and volume – may be reticent to change
- Government procurement mechanisms may not enable government decision makers to fully account for resiliency benefits
- Launches and satellites are procured by two different groups – may be difficult to coordinate shared understanding of requirements and benefits
- Launches are procured by multiple offices for multiple purposes – may be difficult to establish mechanisms to purchase launches such that they are actually (not just theoretically) interchangeable
- Government may be reticent to move to shared standards that serve many purposes (as opposed to custom-built government standard that best fits their own purposes)
- Government may have challenges with LaunchU trade space (government will likely have to trade some customization to gain LaunchU benefits)

Key Benefits for Government

Government as a leading customer could catalyze the LaunchU market

- There are likely mission assurance and resiliency benefits to adopting a standardized satellite form factor, like LaunchU
- LaunchU would allow more accessibility and flexibility, allowing greater opportunities for responsive launch
- LaunchU could streamline and increase throughput of satellite manufacturing
- Government faces many unique risks and uncertainties in adopting a LaunchU standard, which the government must actively mitigate to capture full standardization benefits

Commercial smallsat manufacturer and operator benefits

Launch provider benefits

Government benefits

Entrepreneur benefits

Key findings

Entrepreneur Benefits

Potential Benefit	Government
Reduced integration costs	✓
Streamlined pre-launch processes	✓
Enables satellite operators to swap launch vehicles	✓
Enables launch providers to swap satellites	✓
Reduces manufacturing cost	✓
Reduces manufacturing time	✓
Increases transparency of process and costs	✓

- ✓ Research identified another key user community that could benefit from LaunchU: entrepreneurs
- ✓ Reduced time to manufacture satellites could enable faster operations and technology demonstration, key for entrepreneurs and emerging companies
- ✓ Increased transparency of process and costs helps make space more accessible to new-to-space businesses
- ✓ Reduces risks and uncertainties for entrepreneurs

Makes Development and Launch More Transparent for Entrepreneurs

Benefit

- Many entrepreneurs are new to space, or are new to managing the end-to-end satellite process
- LaunchU standard provides context of steps involved (by product)
- Gives entrepreneurs a clearly defined starting point, path, and, potential suppliers

Confirmed through Bryce assessment

- Little open source guidance on how to develop and launch satellites, closest is CubeSat
- Experts agree that a standard would simplify the process for entrepreneurs
  - Provides mass and a volume and design target
  - Increases transparency into end-to-end costs, including launch cost
  - Provides a sense of realism in time and cost requirements, key to accurately estimating time to market
- Experts agree standard would provide context, understanding of total cost/kg
- Reduces required engineering work – within the standard engineering work has already been done, just customize to specific application
  - CubeSats demonstrate this model can work
  - If successful, creates market where entrepreneurs can buy mass produced parts from multiple suppliers

LaunchU reduces risk and uncertainties for entrepreneurs

Makes Development Timeline Less Expensive and Faster for Entrepreneurs

Benefit

- Time to demonstration/market is crucial in many start-up business plans
- LaunchU standardization allows entrepreneurs to shorten these timelines

Confirmed through Bryce assessment

- Development and manufacturing is time consuming for entrepreneurs
- Many entrepreneurs start by building a single demonstration satellite, which can be expensive and time consuming
- LaunchU would reduce required engineering work for emerging companies – within the standard engineering work has already been done, just customize to specific application
  - CubeSats demonstrate this model can work
  - If successful, creates market where entrepreneurs can buy mass produced parts from multiple suppliers
- LaunchU standard could allow entrepreneurs to capture some benefits of scale (even if they have not yet scaled their own operation)

Key Benefits for Entrepreneurs

LaunchU could help enable more entrepreneurs to take their ideas to market

- Using the LaunchU standard provides a clear framework for developing a new satellite
- LaunchU standard can reduce individual engineering work
- LaunchU standard could enable faster technology demonstration and operations
- LaunchU reduces risks and uncertainties in development and launch processes

Commercial smallsat manufacturer and operator benefits

Launch provider benefits

Government benefits

Entrepreneur benefits

Key findings

Key Findings

- ✓ All experts agreed that the LaunchU standard benefits launch providers, satellite manufacturers and operators, government, and entrepreneurs
- ✓ All experts were aware of the LaunchU standard
- ✓ All participants are interested in continuing discussions of smallsat standardization
- ✓ Most participants agreed market is moving toward larger more capable satellites in line with LaunchU standards

Findings confirmed hypothesized benefits and identified beneficial use cases

Key Benefits for all Business Sectors

Satellite Manufacturers/Operators

- There are proven cost and time benefits to adopting a standardized satellite form factor, like LaunchU
- Standardizing form factor and reducing customization provides economies of scale for both manufacturers and operators
- Standardizing form factor and reducing customization increases competition, expanding customer markets for satellite manufacturers and increasing supply chain options for satellite operators

Launch Providers

- There are proven cost and time benefits to adopting a standardized satellite form factor, like LaunchU
- LaunchU can greatly simplify launch processing by significantly decreasing required engineering analyses
- Streamlined launch processing reduces burden on launch providers and allows them to offer customers faster access to space
- LaunchU allows launch providers to open up more launch opportunities through multi-manifesting and ability to replace payloads if one drops out (more efficient for both launch provider and satellite operators)

Government

- There are likely responsive space and resiliency benefits to adopting a standardized satellite form factor, like LaunchU
- LaunchU would allow more accessibility and flexibility with launch
- LaunchU could streamline and increase throughput of satellite manufacturing
- Government faces many unique risks and uncertainties in adopting a LaunchU standard, which the government must actively mitigate to capture full standardization benefits

Entrepreneurs

- Using the LaunchU standard provides a clear framework for developing a new satellite
- LaunchU standard can reduce individual engineering work
- LaunchU standard could enable faster technology demonstration and operations
- LaunchU reduces risks and uncertainties in development and launch processes

Confirmed Hypothesized Benefits

Potential Benefit	Commercial Smallsat Operators and Manufacturers	Commercial Launch Provider	Government	Entrepreneurs
Reduced integration costs		✓	✓	✓
Streamlined pre-launch processes	✓	✓	✓	✓
Enables satellite operators to swap launch vehicles	✓	✓	✓	✓
Enables launch providers to swap satellites	✓	✓	✓	✓
Reduces manufacturing cost	✓		✓	✓
Reduces manufacturing time	✓		✓	✓
Increases transparency of process and costs				✓