



# TRUSTPOINT

*Resilient GPS for the Automated and Augmented World*

## Leveraging a LEO Satellite Constellation for Accurate & Reliable PNT

*PNTAB 27, Redondo Beach, CA,  
November 16, 2022*

Patrick Shannon  
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***Less is More – The Case for Going Aggressively Small***

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# Overview

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- TrustPoint Company Overview
- The Goal
- Small Satellites
- Small Orbits
- Small Waves
- Key Conclusions
- Recommendations



# TrustPoint Company Overview

- Founded 2020
- Closed Initial Funding Mid-2021 from Blue-Chip Space Investor Data Collective Venture Capital (DCVC)
- Facilities in Northern Virginia (Dulles) and Silicon Valley (Mountain View)
- 10 Member Team Led by Proven Executives and Entrepreneurs
- Segment Focus → 80% Commercial, 20% Defense
- Technology Focus → Satellite Payloads, Signals, and Receivers

Autonomous Vehicles



National Security



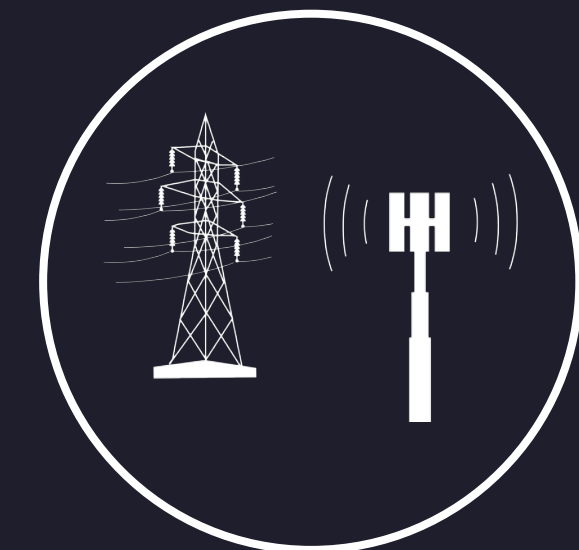
Aviation



Apps & Gaming



Infrastructure



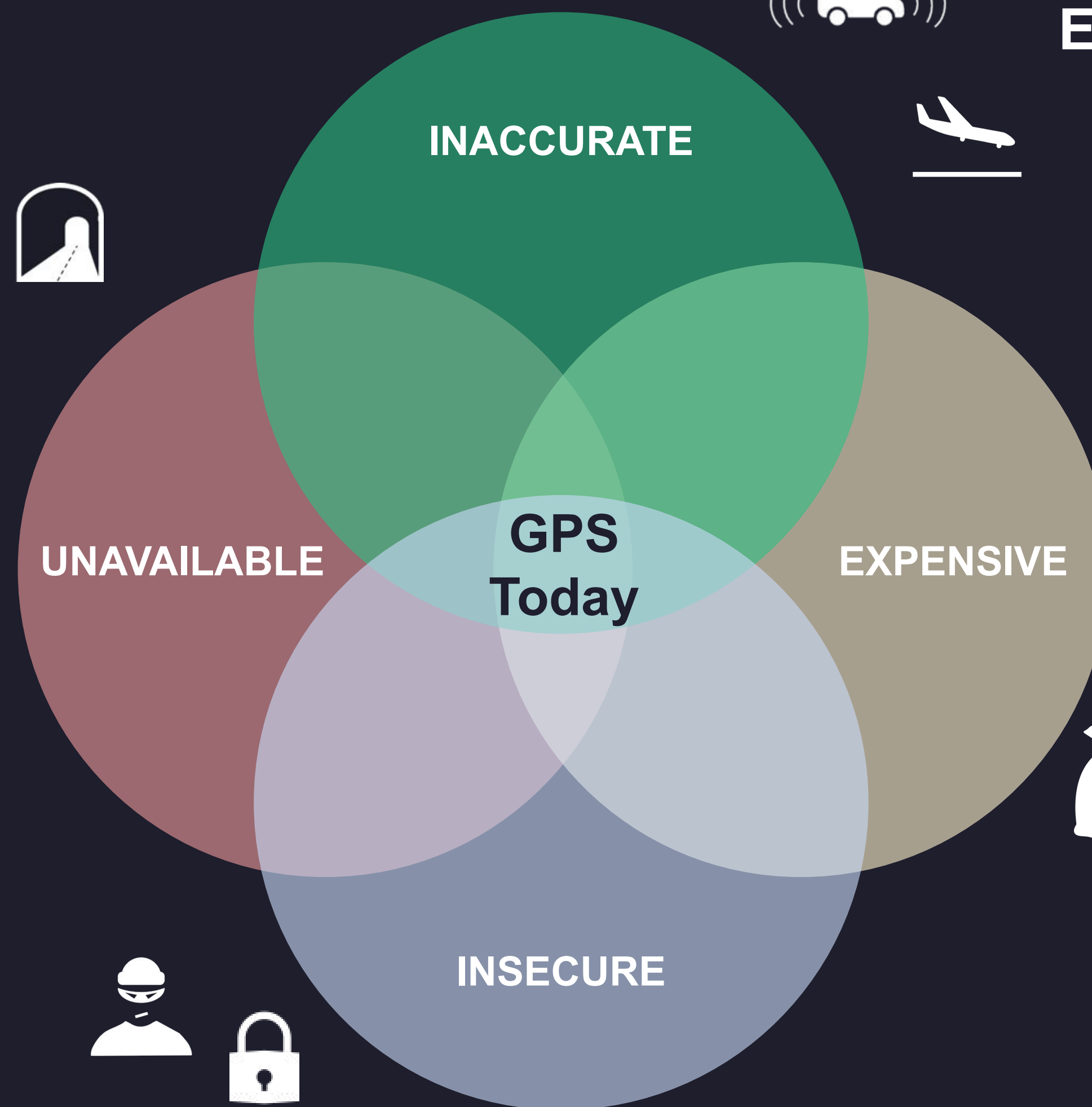


# THE PROBLEM

**SLOW TO ACQUIRE  
EASY TO DISRUPT**



**ERROR PRONE**



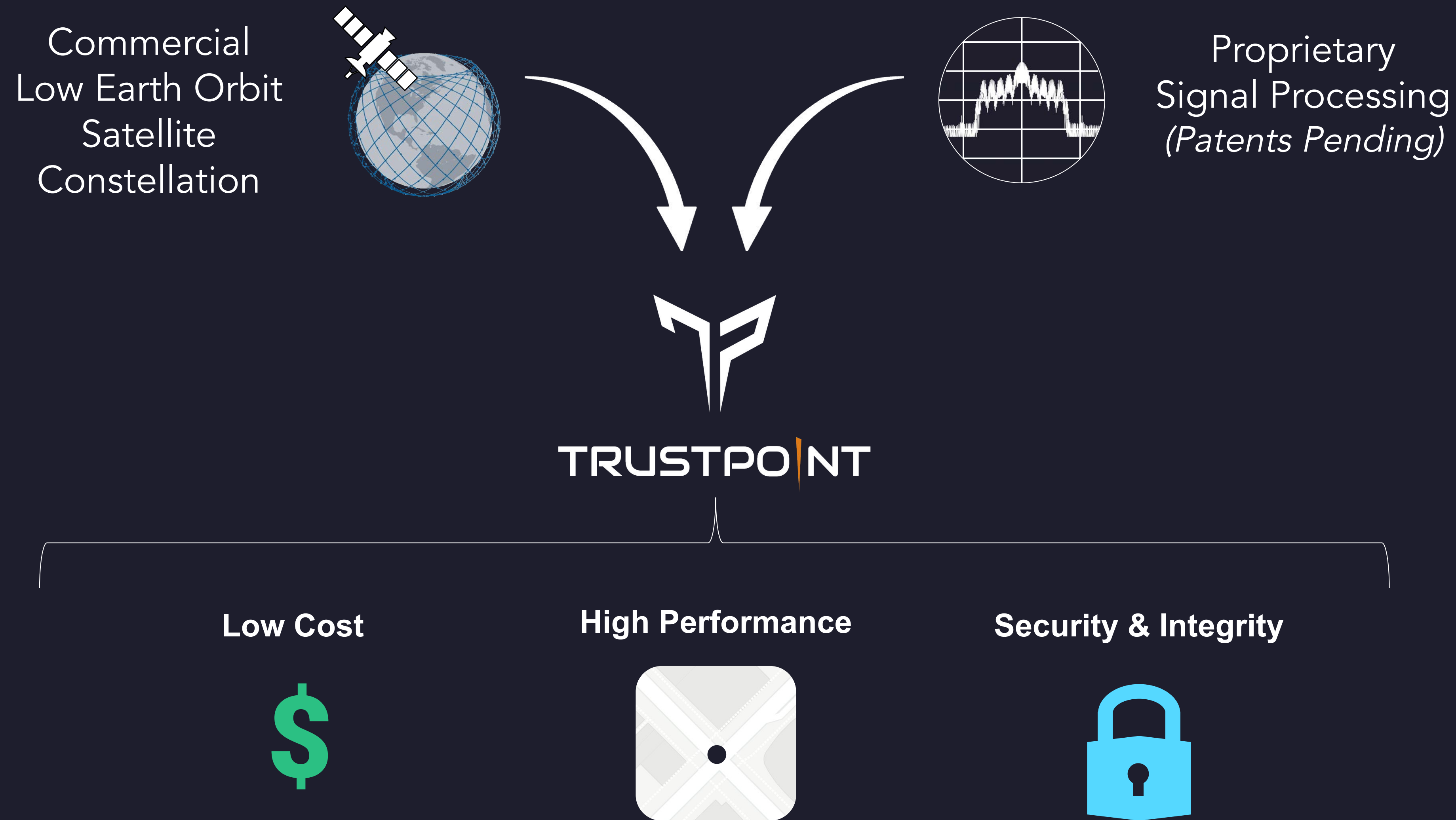
**COSTLY TO AUGMENT**

**EASY TO FAKE**



Today's GPS Suffers in Four Ways - All Four Issues Must Be Addressed for Key 21st Century Applications

# THE SOLUTION





# What is the Goal?

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## What is the Goal?

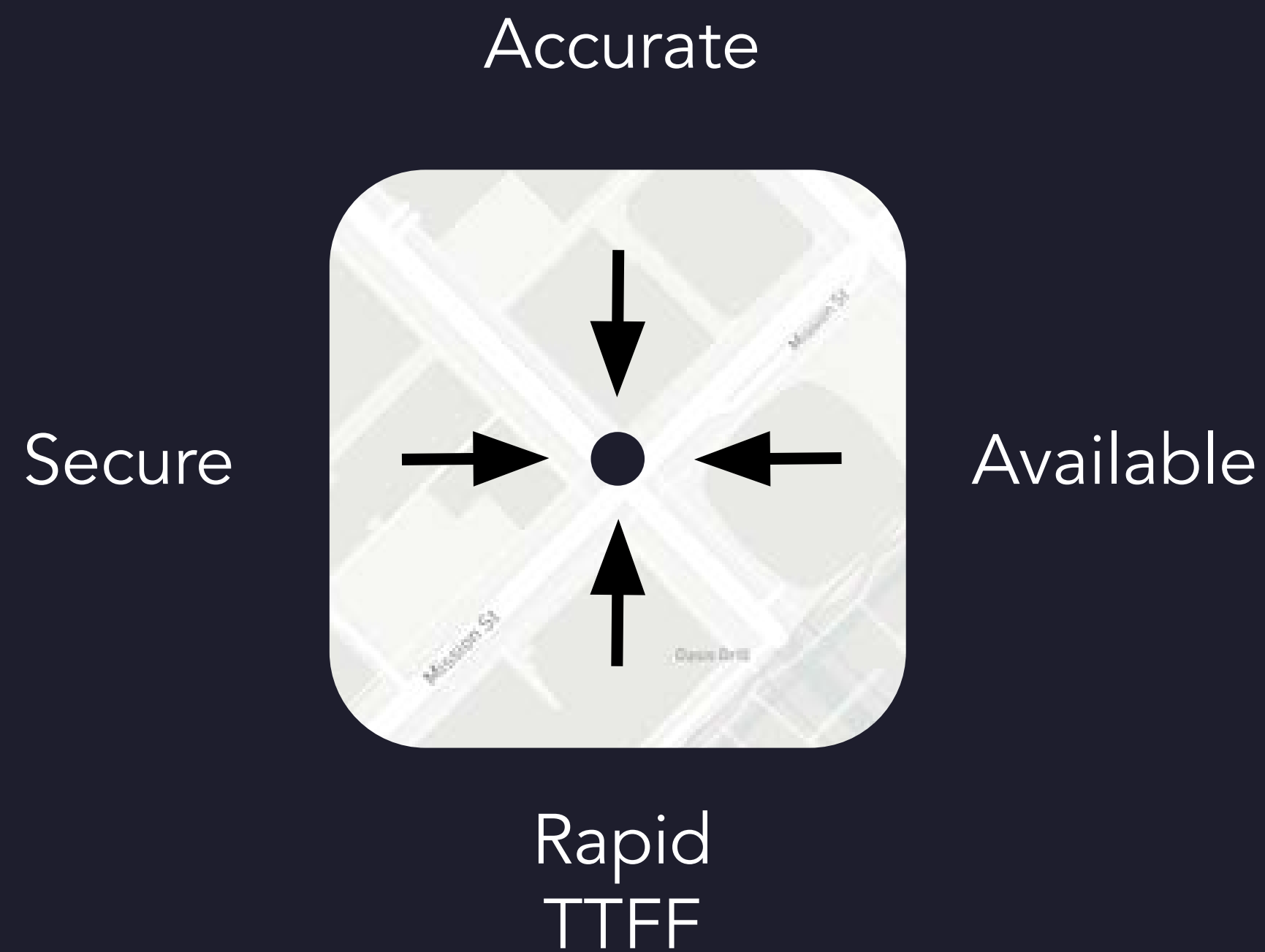
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*What are we trying to achieve that we haven't with heritage technologies, systems and services?*

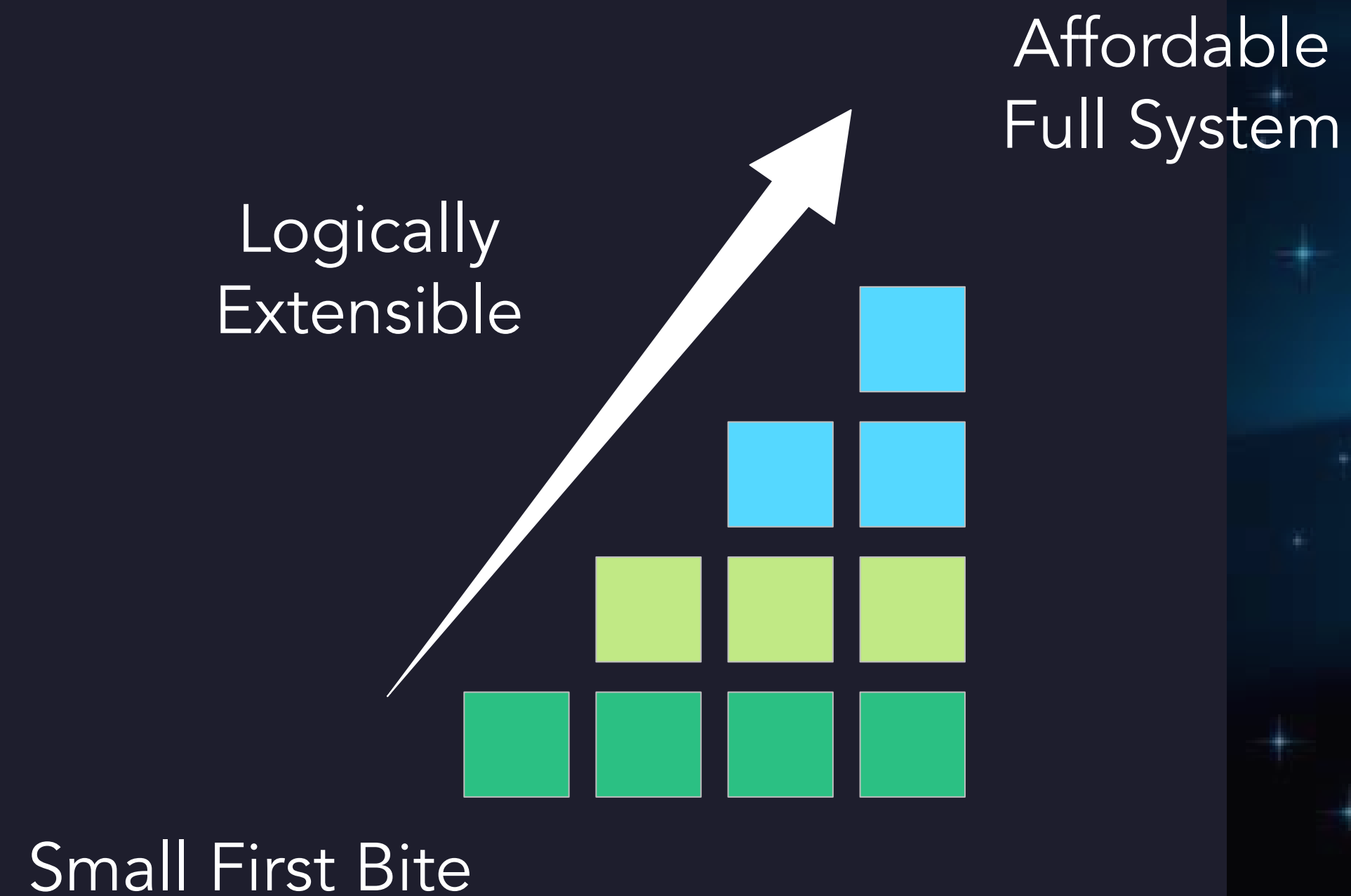


# The Goal (1 of 2)

## High Performance



## Scalable



# The Goal (2 of 2)

## Resilience

Graceful Degradation



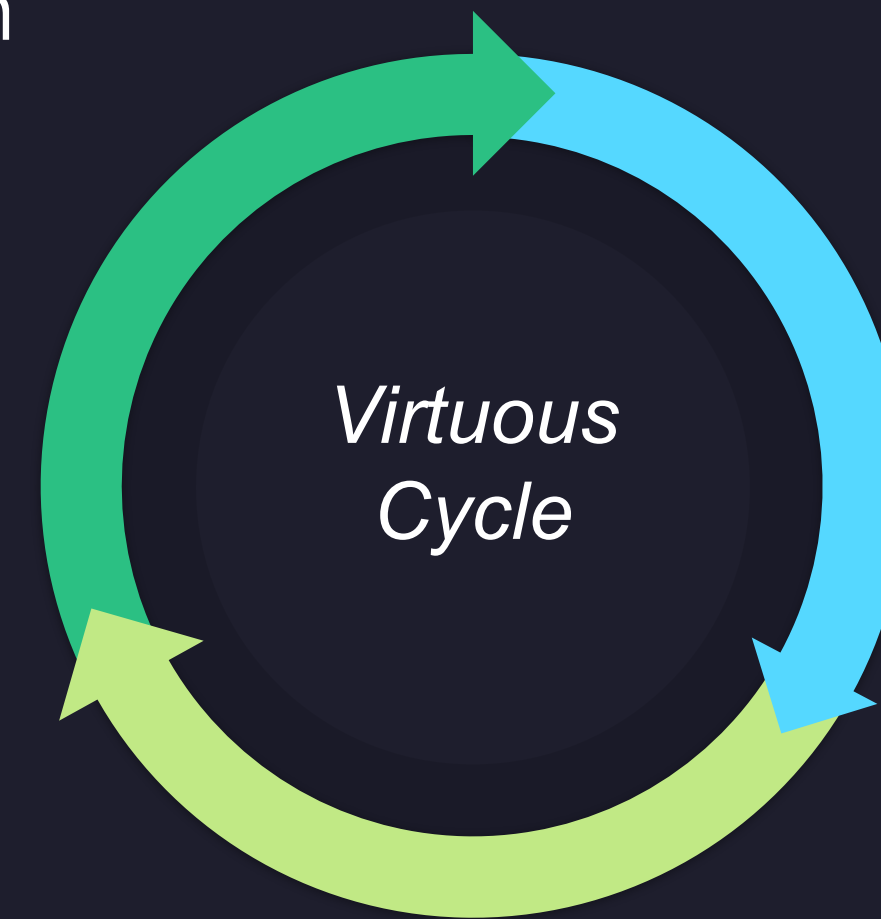
Flexibility

Responsiveness

## Future Proofing

Launch

Build



Test





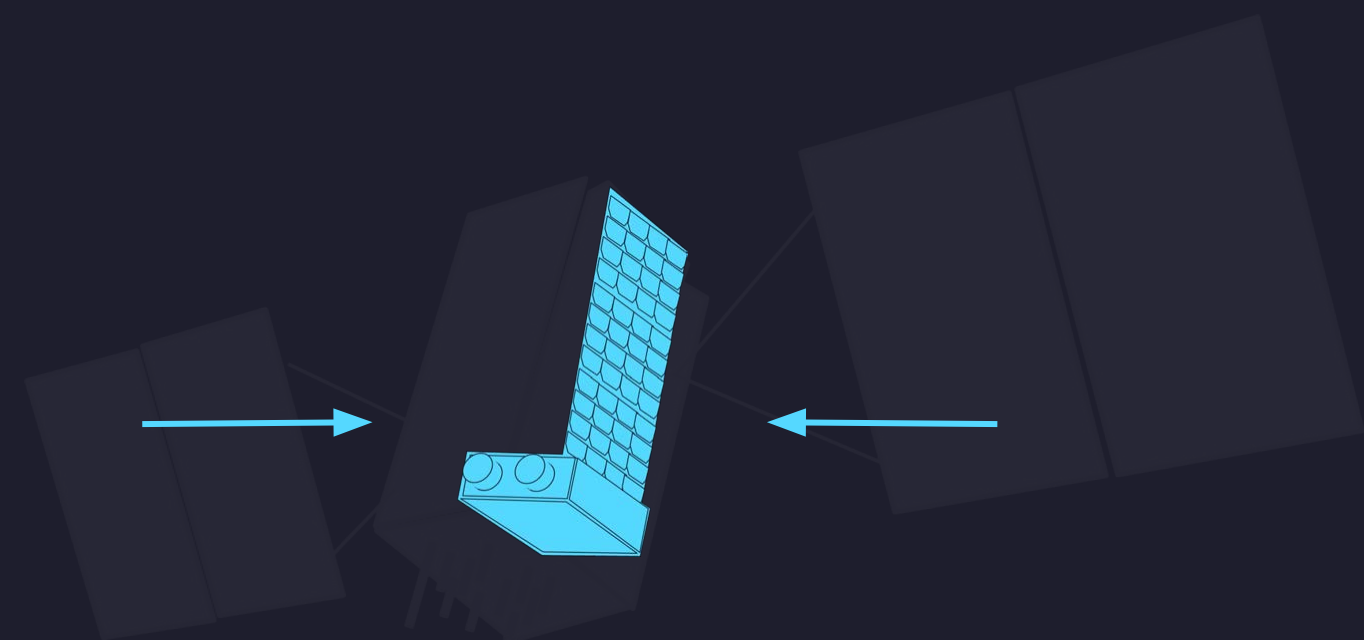
# How Do We Get There?

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# A Potent Trifecta

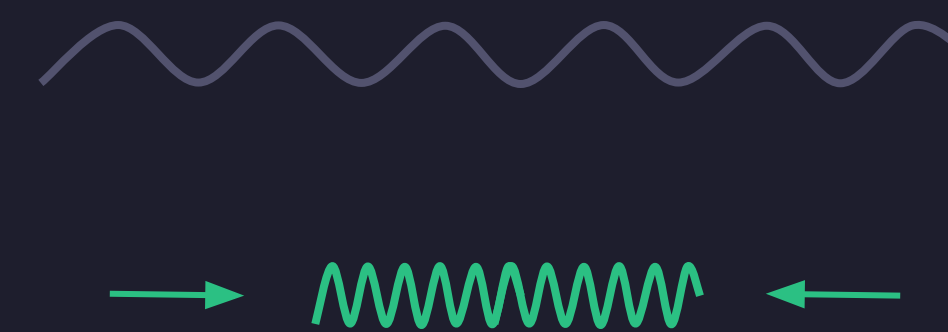
Small Satellites



Small Orbits

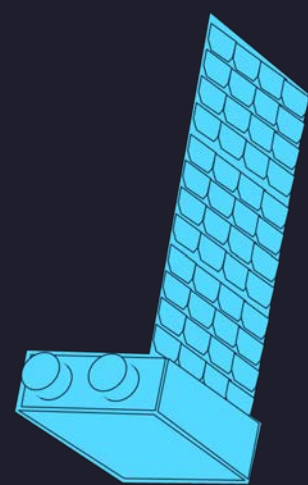


Small Waves





# Small Satellites



6U CubeSats  
10 kgs  
~50 Watts OAP

High Performance



Scalable



Resilient

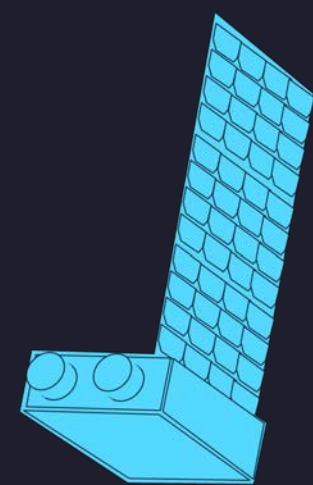


Future Proof





# Small Satellites



6U CubeSats  
10 kgs  
~60 Watts OAP

- Low Cost

High Performance



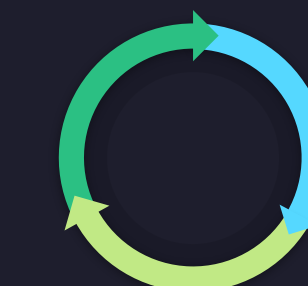
Scalable



Resilient



Future Proof



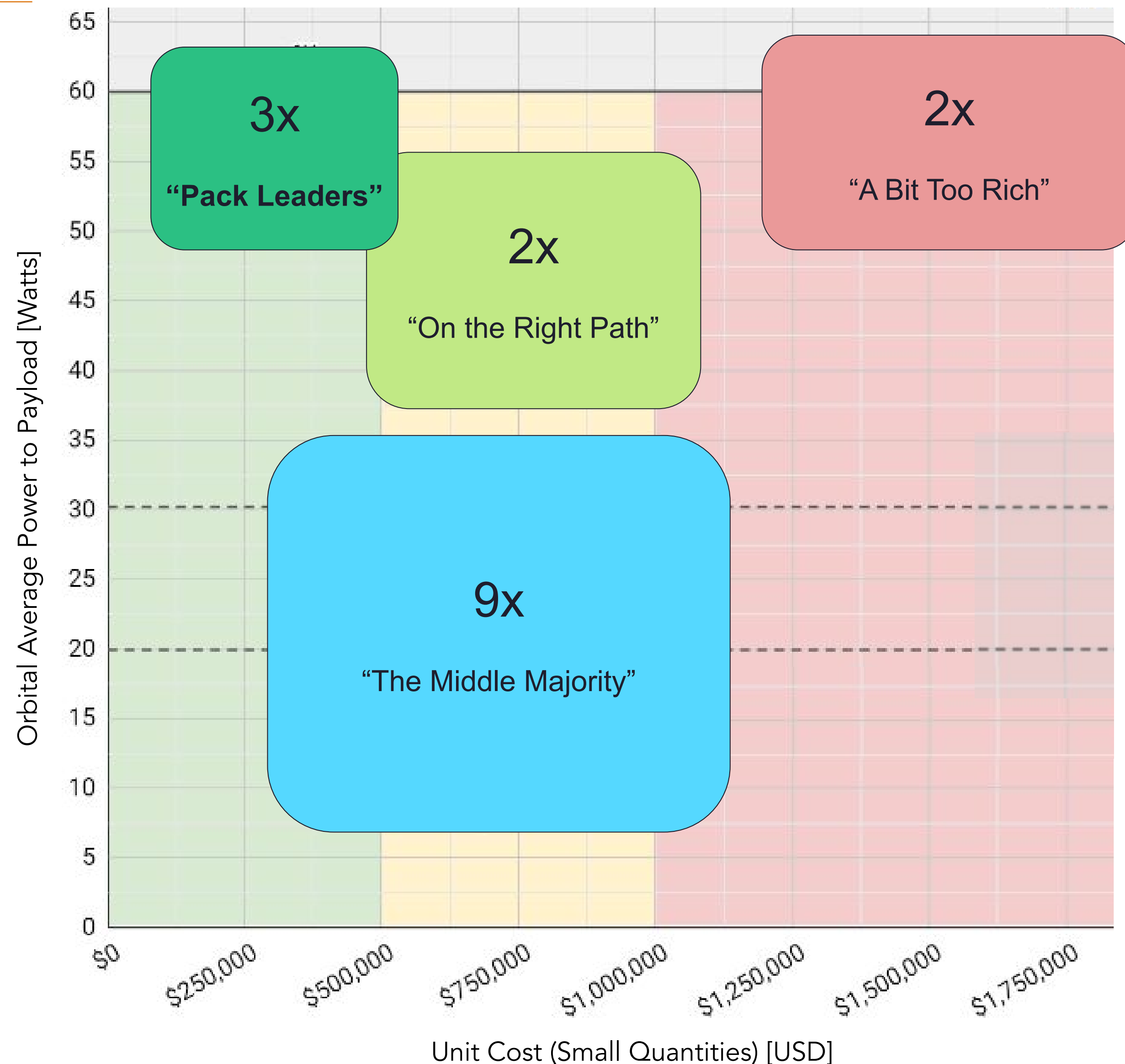


# A Healthy CubeSat Supplier Base

- 16 Platforms Reviewed (3U, 6U, 12U)
- Mix of TRL-6 to TRL-9
- Strong Advancement of CubeSat Platform Technology in Last 3 Years
  - 2-3x Increase in OAP to Payload
  - 30-50% Reduction in Cost
- 2-3 More Platforms Expected to Achieve "Pack Leader" Status in 2024
- Additional 20-30% Cost Reduction for Large Quantities

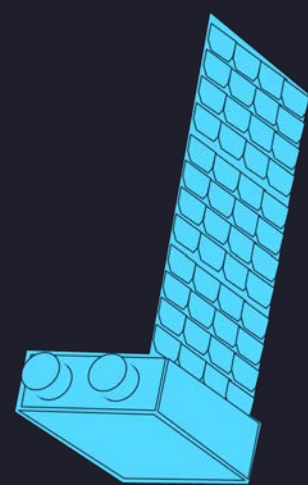
Multiple High Performance \$200K Platforms are Now Available

Platform Cost vs Available Payload Power





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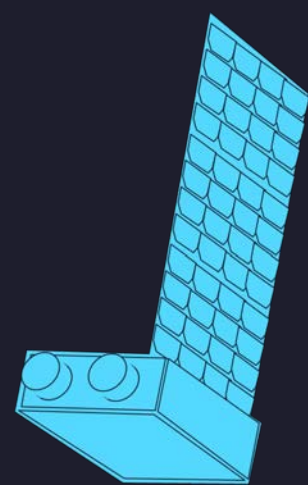
Future Proof





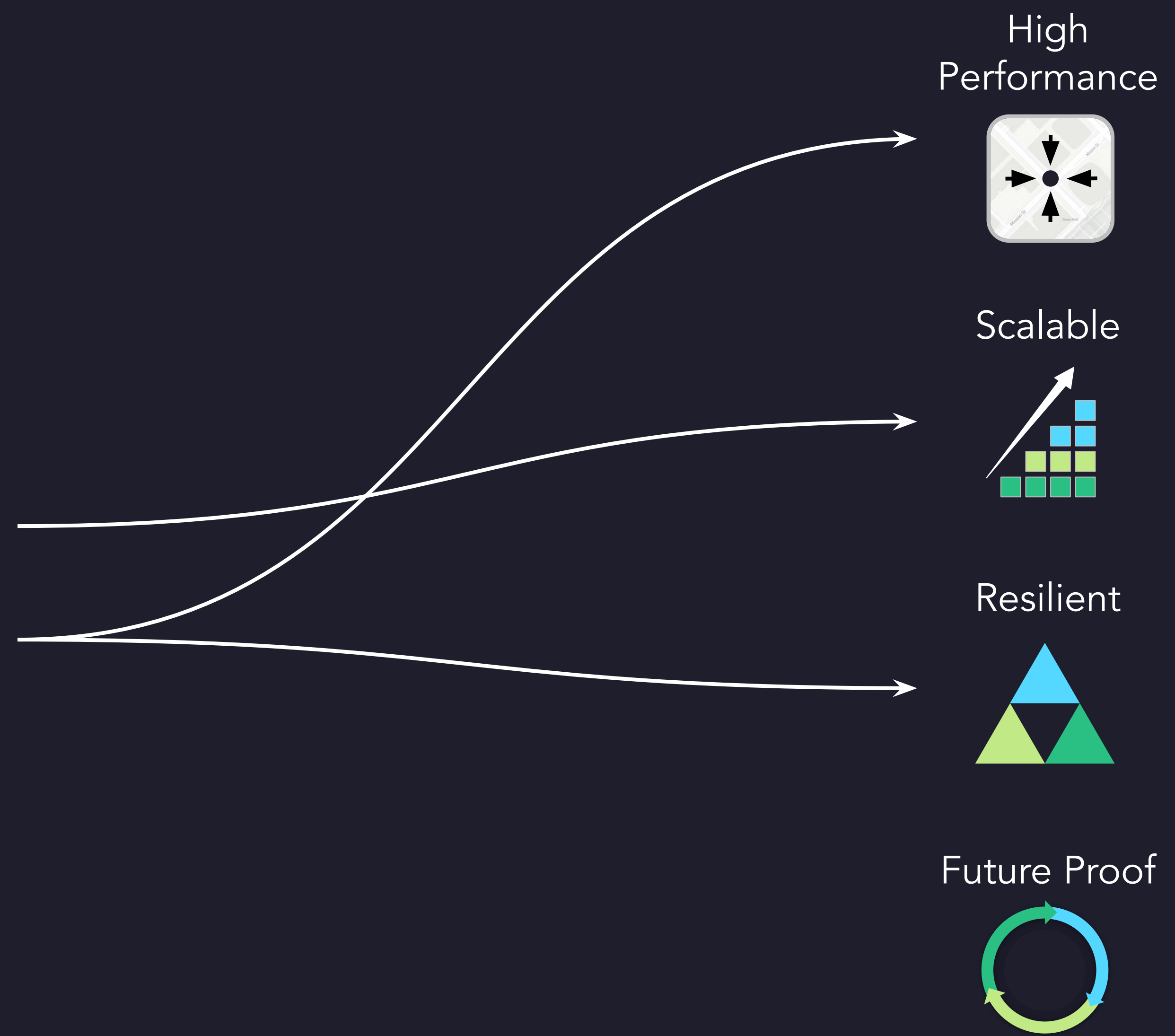


# Small Satellites



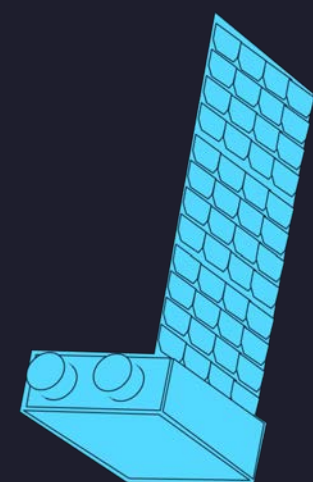
6U CubeSats  
10 kgs  
~60 Watts OAP

- Low Cost
- Many Nodes



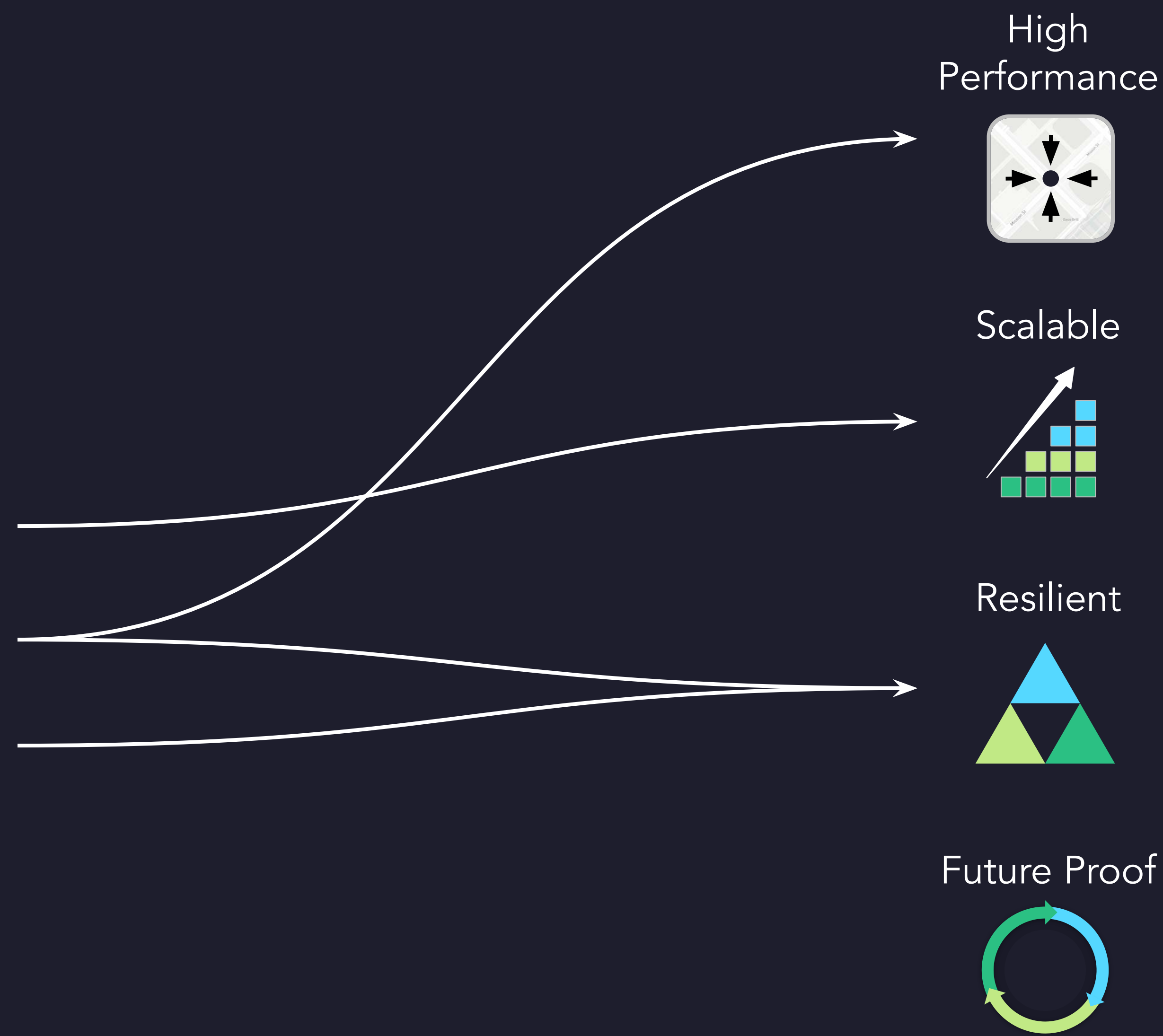


# Small Satellites

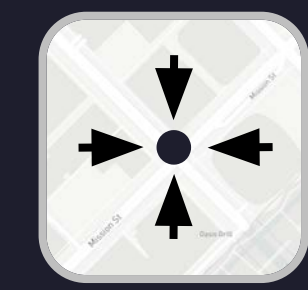


6U CubeSats  
10 kgs  
~60 Watts OAP

- Low Cost
- Many Nodes
- Plentiful Supplier Base



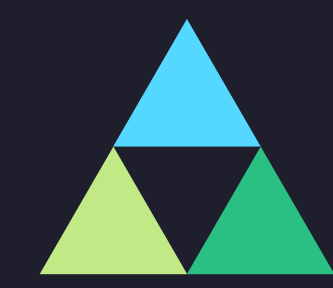
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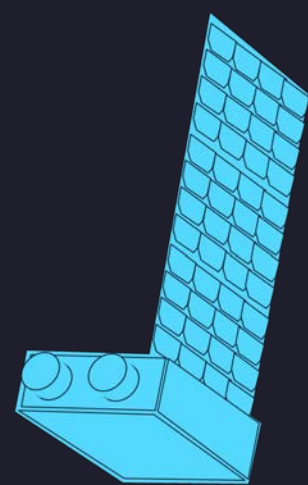


Future Proof



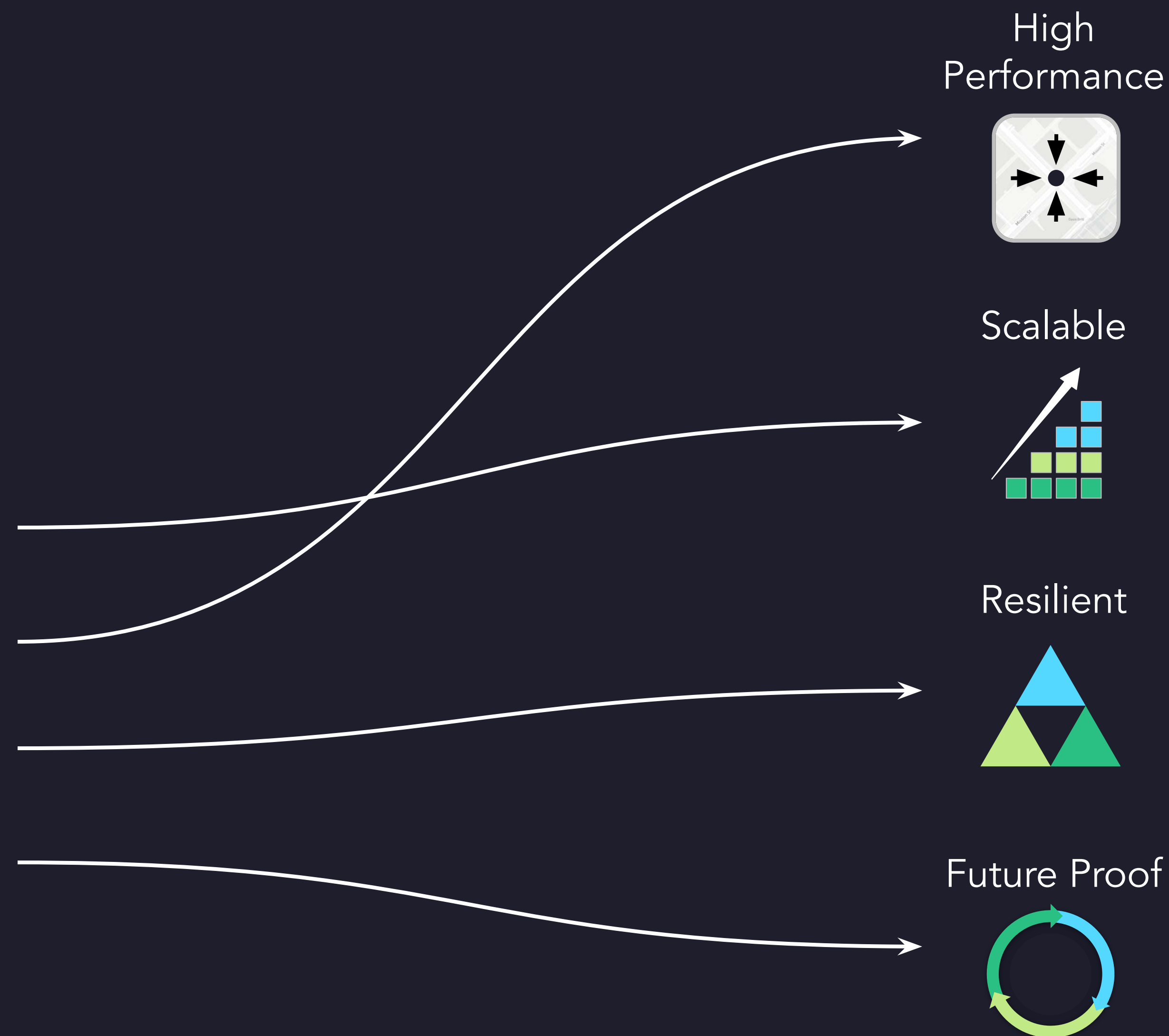


# Small Satellites



6U CubeSats  
10 kgs  
~60 Watts OAP

- Low Cost\*
- Many Nodes
- Plentiful Supplier Base
- Short Build Time





# Short Build Schedules - Iterative Design and Deployment



2G Nokia Phone (2002)  
~64 kbps, 32 MB

15,000x  
Data Rates  
→  
16,000x  
Data Storage



5G iPhone 13 (2021)  
1 Gbps, 512 GB



Early GPS Receivers (1978)

Orders of  
Magnitude  
→



Magellan NAV 1000 (1990)  
\$3000, 600g, 3 Hrs Battery Life

Many Orders of  
Magnitude !!!  
→



Broadcom BCM4778 (2021)  
~\$10, <1g, 2.5x2.5mm, <10mW

Apply Iterative Design to All Levels of Tech Stack With Commercial LEO Approach



# Small Orbits



500 to 800 km  
Easily Accessible  
Below Material Radiation

High Performance



Scalable



Resilient



Future Proof





# Small Orbits



500 to 800 km  
Easily Accessible  
Below Material Radiation

- Low Cost Deployment

High Performance



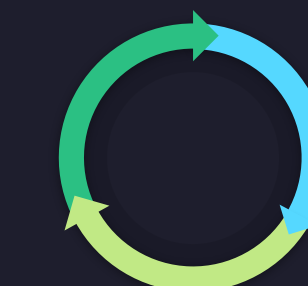
Scalable



Resilient



Future Proof





# Small Orbits



500 to 800 km  
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- Low Cost Deployment
- Low Cost Satellites

High Performance



Scalable



Resilient



Future Proof





# Small Orbits



500 to 800 km  
Easily Accessible  
Below Material Radiation

- Low Cost Deployment
- Low Cost Satellites
- Low Cost Deorbit

High Performance



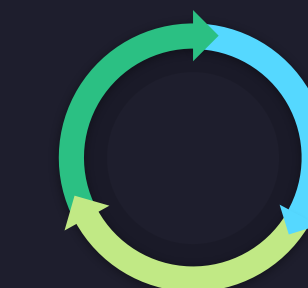
Scalable



Resilient



Future Proof







# Moderate LEO Vs Higher LEO

Moving from 700 km to 1000 km Requires:

- Greater Radiation Tolerance (1.7 → 5 krad/year)
  - More Shielding and More Launch Mass → 5% Increase
  - More Expensive Electronics → 25% Increase
- Larger Power System (~50% More Power to Illuminate to Same Elv Mask)
  - More Launch Mass → 5% Increase
  - More Expensive Power System → 10% Increase
- Greater DeltaV for Deorbit (80 → 160 m/s)
  - More Launch Mass → 10% Mass Increase
  - More Expensive Propulsion System → \$100K Increase
- Greater Reserved Ops Life for Deorbit (1 → 6 Months)
  - More Expensive Satellite Years → 10% Reduction In Ops Life = 11% Cost Increase
- Higher Launch Costs
  - Launch Cost → 25% Increase

50% Launch Cost Increase (\$100K → \$150K)

96% Per Satellite Cost (\$200K → \$400K)



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**83% Per Deployed Satellite Cost Increase (\$300K → \$550K)**



# Moderate LEO Vs Higher LEO

Moving from 700 km to 1000 km Allows:

- Less Total Satellites ( 300 → 200 Satellites for Equivalent Coverage)
  - 33% Less Satellites
  - 33% Less Launches

	700 km System	1000 km System	GPS
Satellite Cost	\$200K	\$400K	-
Launch Cost	\$100K	\$150K	-
Deployed Satellite Cost	\$300K	\$550K	\$500M
Qty in Constellation	300	200	24
Total System Cost	\$90M	\$110M	\$12B
Operational Life	~5 Years	~5 Years	15 Years
Annualized System Cost	\$18M	\$22M	\$800M

Final Result → 20% Increase in System Cost



# Moderate LEO Vs Higher LEO

Moving from 700 km to 1000 km Allows:

- Less Total Satellites (200 → 200 Satellites for Equivalent Coverage)

1

Propulsion and Power Systems for 1000 km System Not Available, Will Require Material R&D Cost & Schedule

2

Notional 12 Month Schedule Delta for a 1000 km System Could Create \$10Ms in Lost Opportunity Costs

Annualized System Cost

\$18M

\$22M

\$800M

Final Result → 20% Increase in System Cost



# Small Orbits



500 to 800 km  
Easily Accessible  
Below Material Radiation

- Low Cost Deployment
- Low Cost Satellites
- Low Cost Deorbit

High Performance



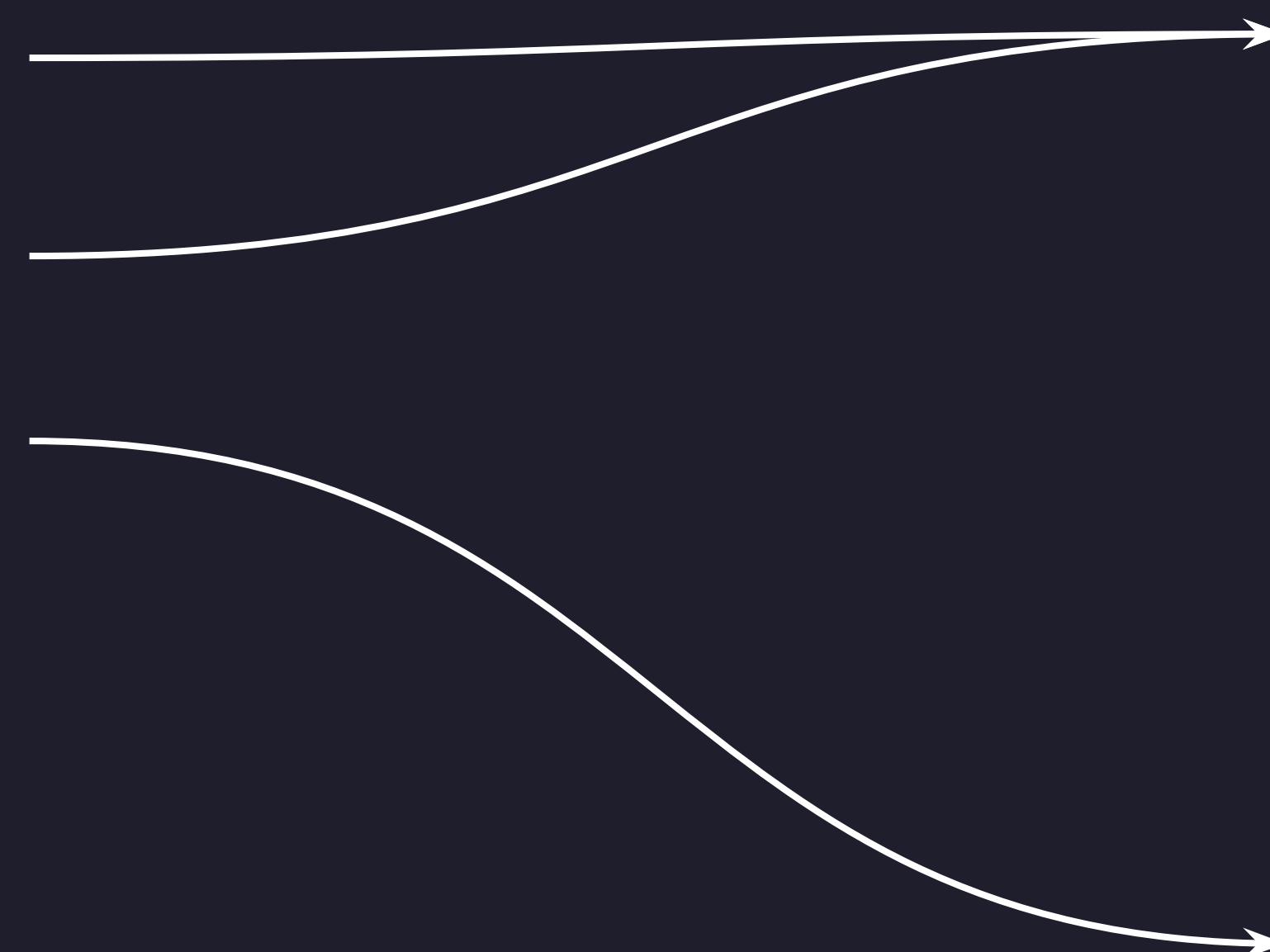
Scalable



Resilient



Future Proof





# Small Orbits



500 to 800 km  
Easily Accessible  
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- Low Cost Deployment
- Low Cost Satellites
- Low Cost Deorbit
- Diverse Launch Options

High Performance



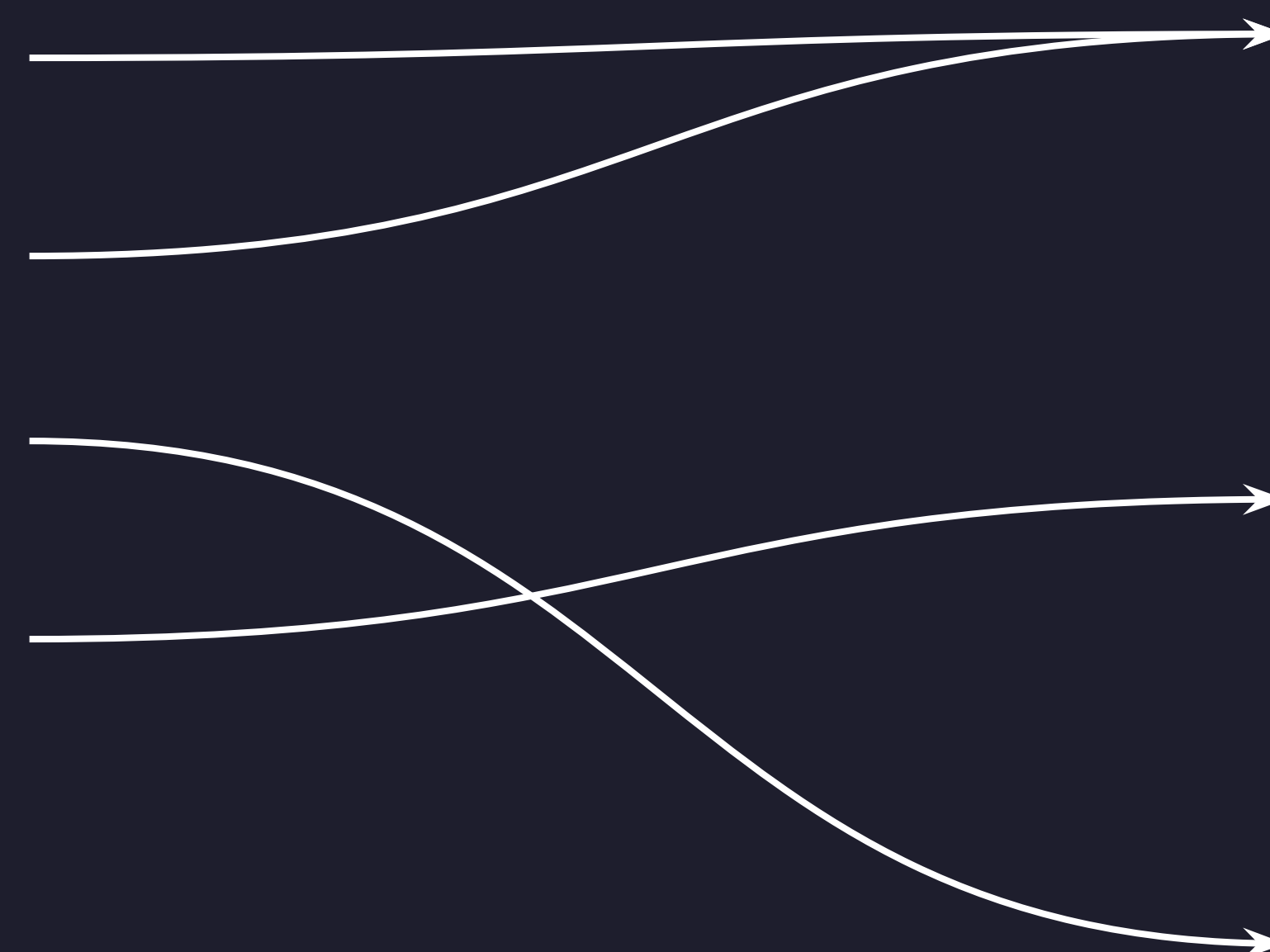
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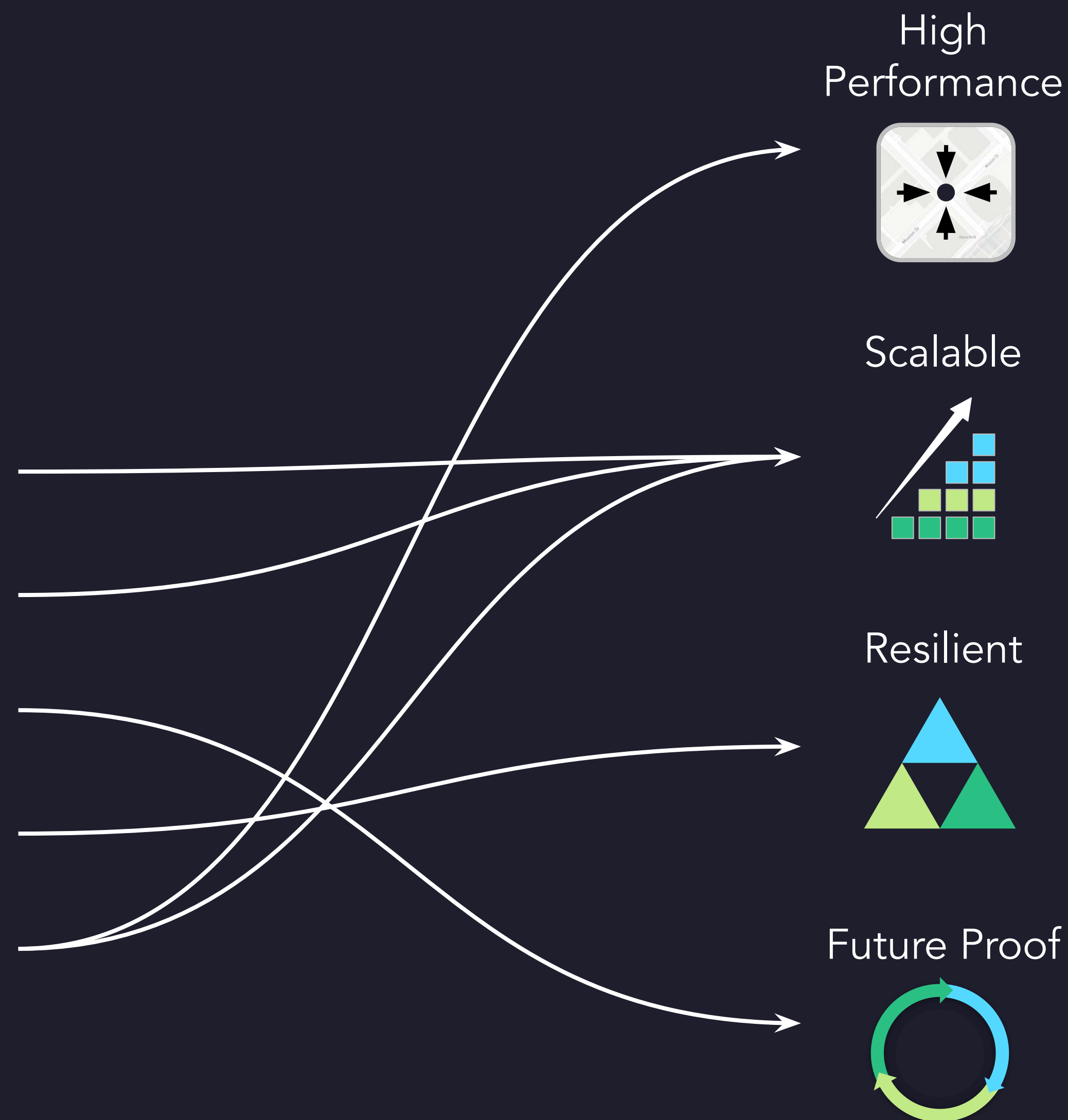


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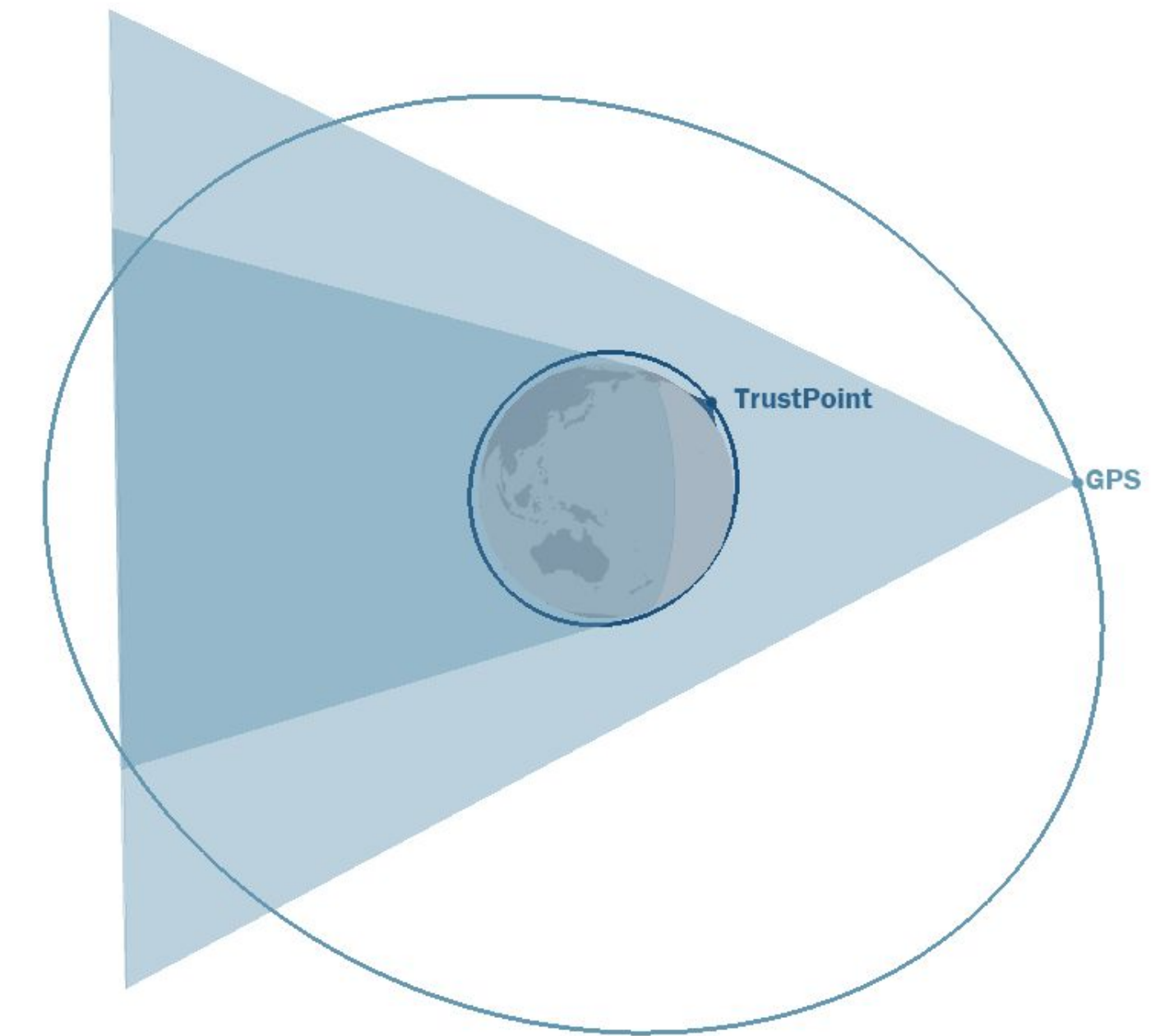
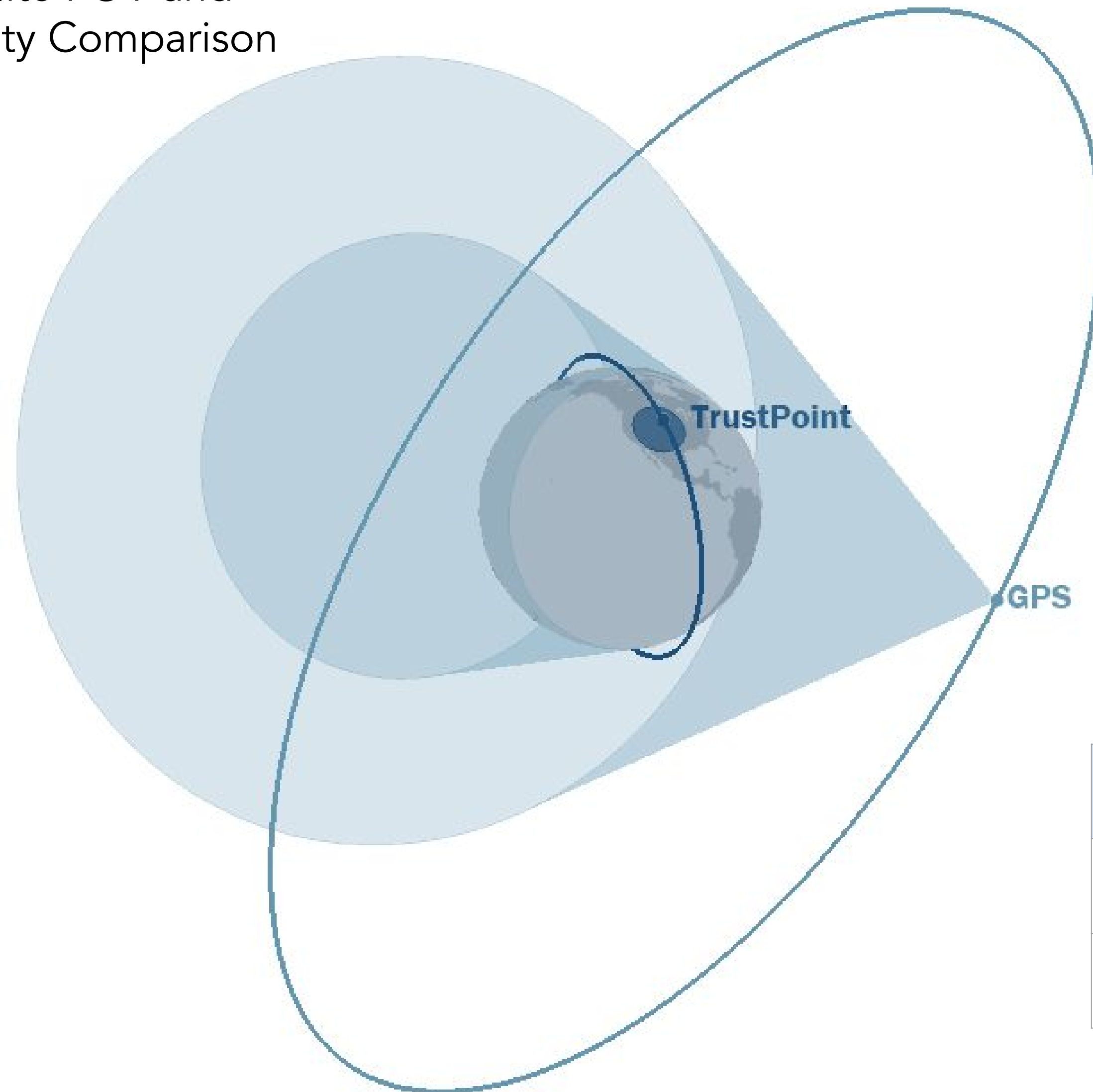
- Low Cost Deployment
- Low Cost Satellites
- Low Cost Deorbit
- Diverse Launch Options
- Favorable Geometry





# Favorable Geometry - Angular Velocity and Field of View

Single Satellite FOV and Angular Velocity Comparison



Key Geometric Factors	GPS @ MEO	LEO
Instantaneous Field of View	~200M km <sup>2</sup>	<10M km <sup>2</sup>
Pass Time	3 to 4 Hrs	6 to 12 Mins





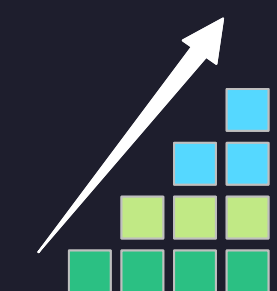
# Small Waves *aka....Higher Frequencies!*



High Performance



Scalable



Resilient



Future Proof





# Small Waves *aka....Higher Frequencies!*



- Compact User Antennas

High Performance



Scalable



Resilient



Future Proof





# Opportunity for Compact High Performance Antennas

- Controlled Reception Pattern Antennas (CRPAs) Can Offer Up to Another 40+ dB Improvement to J/S
- CRPA Antennas (7 Element and 4 Element) are Relatively Large and Heavy, Making them Inadequate for Smaller Form Factor Devices (IoT, Mobile Phones, Wearables, Drones etc)
- Antenna Size and Mass are Proportional to Wavelength
- A Move From 1575 MHz ( $\lambda = 19\text{cm}$ ) to 5.02 GHz ( $\lambda = 6\text{cm}$ ) Provides an Opportunity to Reduce Size by 70% and Mass by 90%

		Diameter [in]	Radius [in]	Area [sq in]	Mass [oz]	Mass/Area [oz/sq in]
L-Band	7 Element	6.3	3.15	31.17	20.8	0.67
	4 Element	3.5	1.75	9.62	8.4	0.87
C-Band	7 Element	1.98	0.99	3.07	2.05	0.67
	4 Element	1.10	0.55	0.95	0.83	0.87
		<b>Size Ratio</b>	<b>31%</b>	<b>Mass Ratio</b>	<b>10%</b>	

7NF-6.29CG1215P-XS-X ANTENNA FAMILY  
7-Element CRPA with Cable Outputs



**MECHANICAL**

Dimensions	Diameter: 6.30" Height: 0.75"
Weight	20.8 oz (Typical)

4NC-3.5CG1215P-XX-X-7.5EM ANTENNA FAMILY  
GPS L1/L2 CRPA with FRPA mounting holes



**MECHANICAL**

Dimensions	Diameter: 3.5" Height: .70"
Weight	8.4 oz



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# Opportunity for Compact High Performance Antennas

7NF-6.29CG1215P-XS-X ANTENNA FAMILY  
7-Element CRPA with Cable Outputs

- Controlled Reception Pattern Antennas (CRPAs) Can Offer Up to ~50 dB of

- CRPA Heavy Mobile

- Antenna

- A Mobile Opportunity

1

Antenna Size and Weight are as Important (if not more) to Commercial Sector as They are to National Security

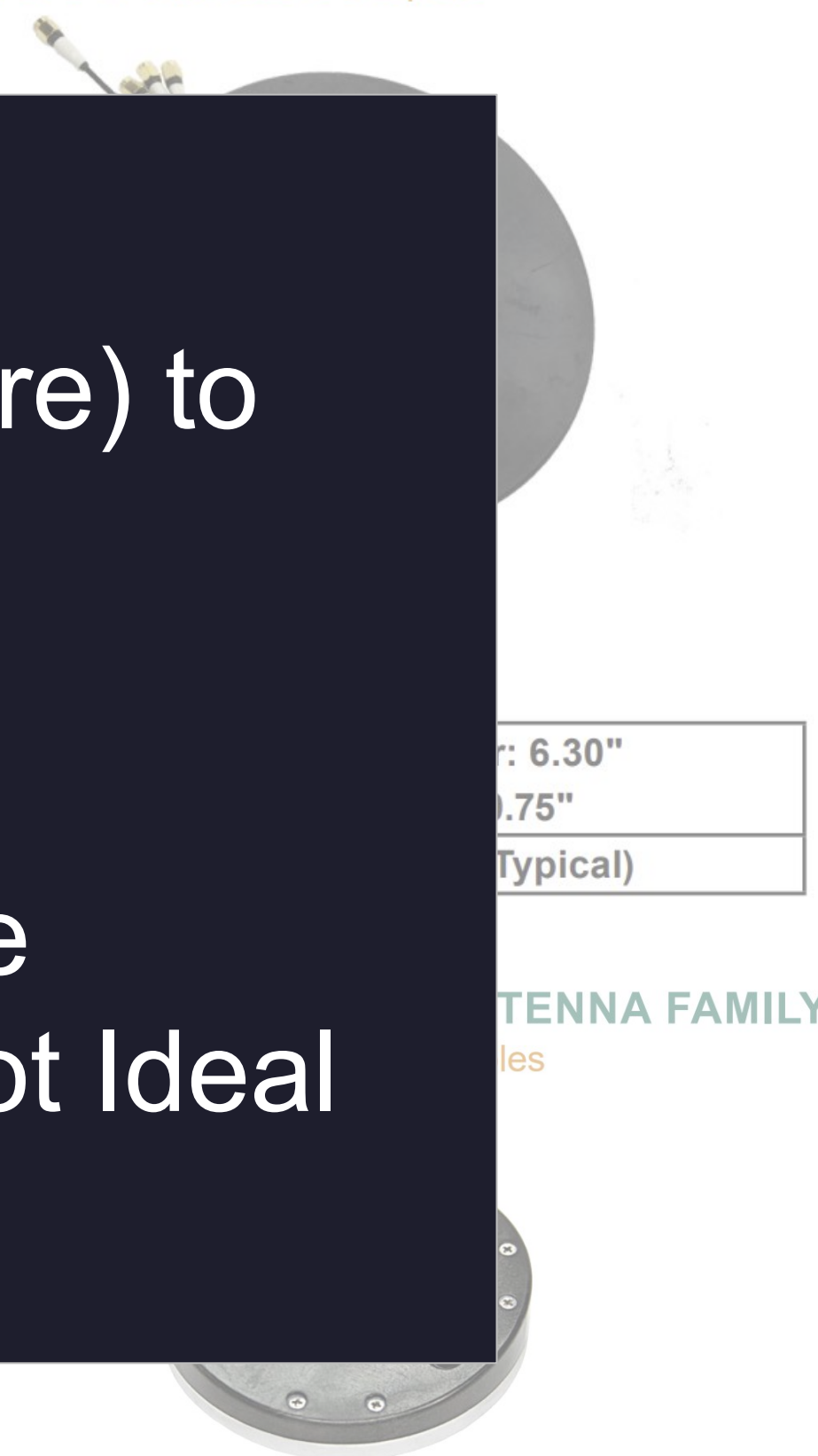
2

Mobile Phones, IoT Devices, and Wearables all Have Extreme SWaP Limitations. L-band Works, but it's Not Ideal

L-Band	7 Element	6.3	3.15	31.17	20.8	0.67
	4 Element	3.5	1.75	9.62	8.4	0.87
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### MECHANICAL

Dimensions	Diameter: 3.5" Height: .70"
Weight	8.4 oz



Dimensions	Diameter: 6.30" Height: .75" (Typical)
------------	--

ANTENNA FAMILY  
les



# Small Waves

*aka....Higher Frequencies!*



Above 2 GHz  
Below 10 GHz

- Compact User Antennas





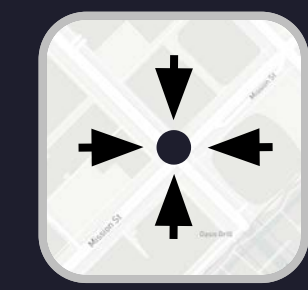
# Small Waves *aka....Higher Frequencies!*



- Compact User Antennas
- Compact Satellite Antennas



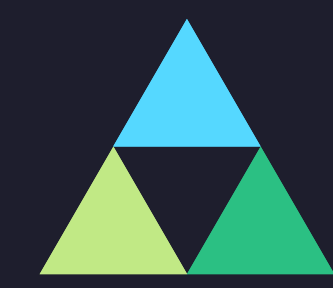
High Performance



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Future Proof

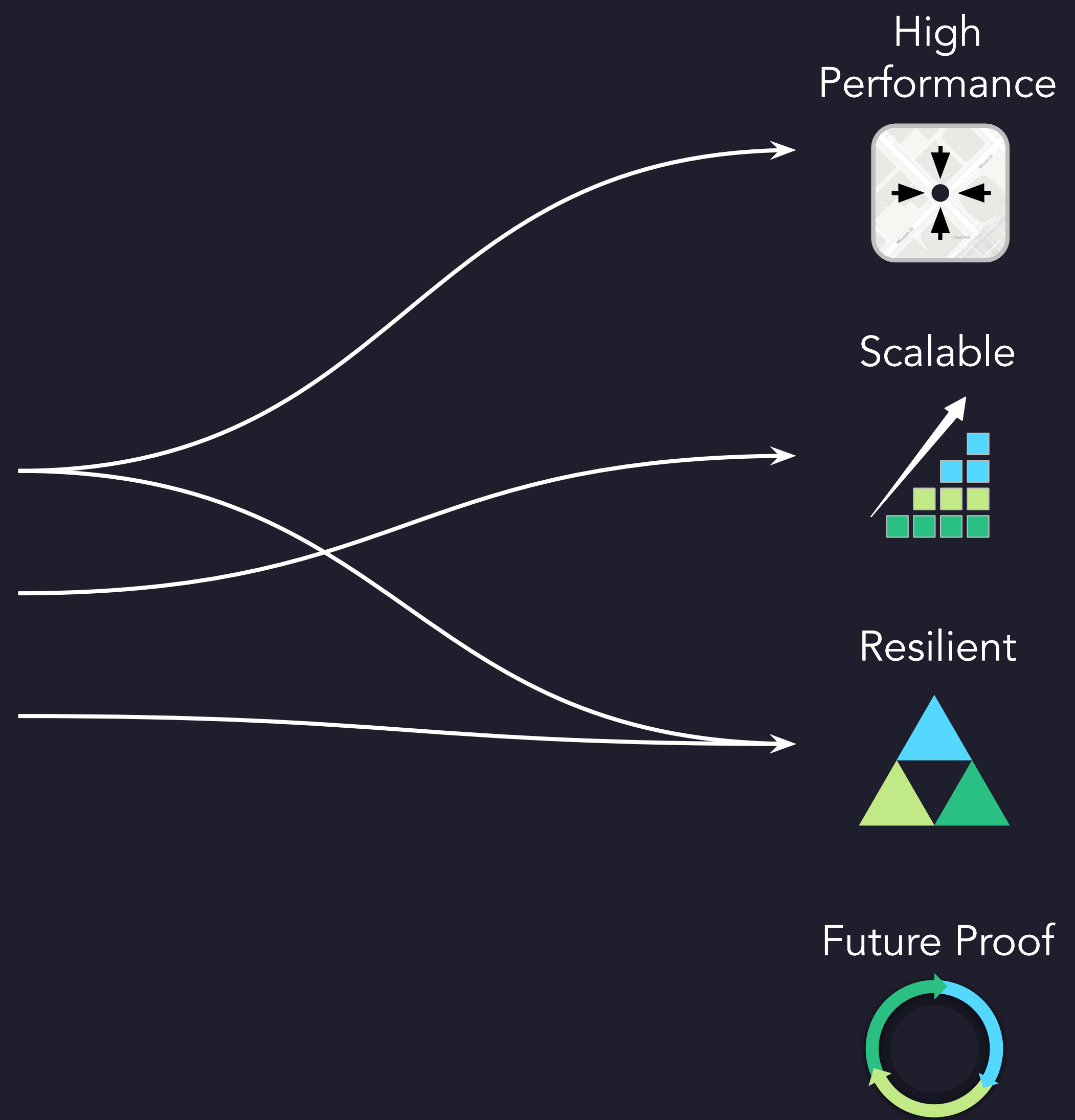




# Small Waves *aka....Higher Frequencies!*



- Compact User Antennas
- Compact Satellite Antennas
- Absolute Frequency Agility



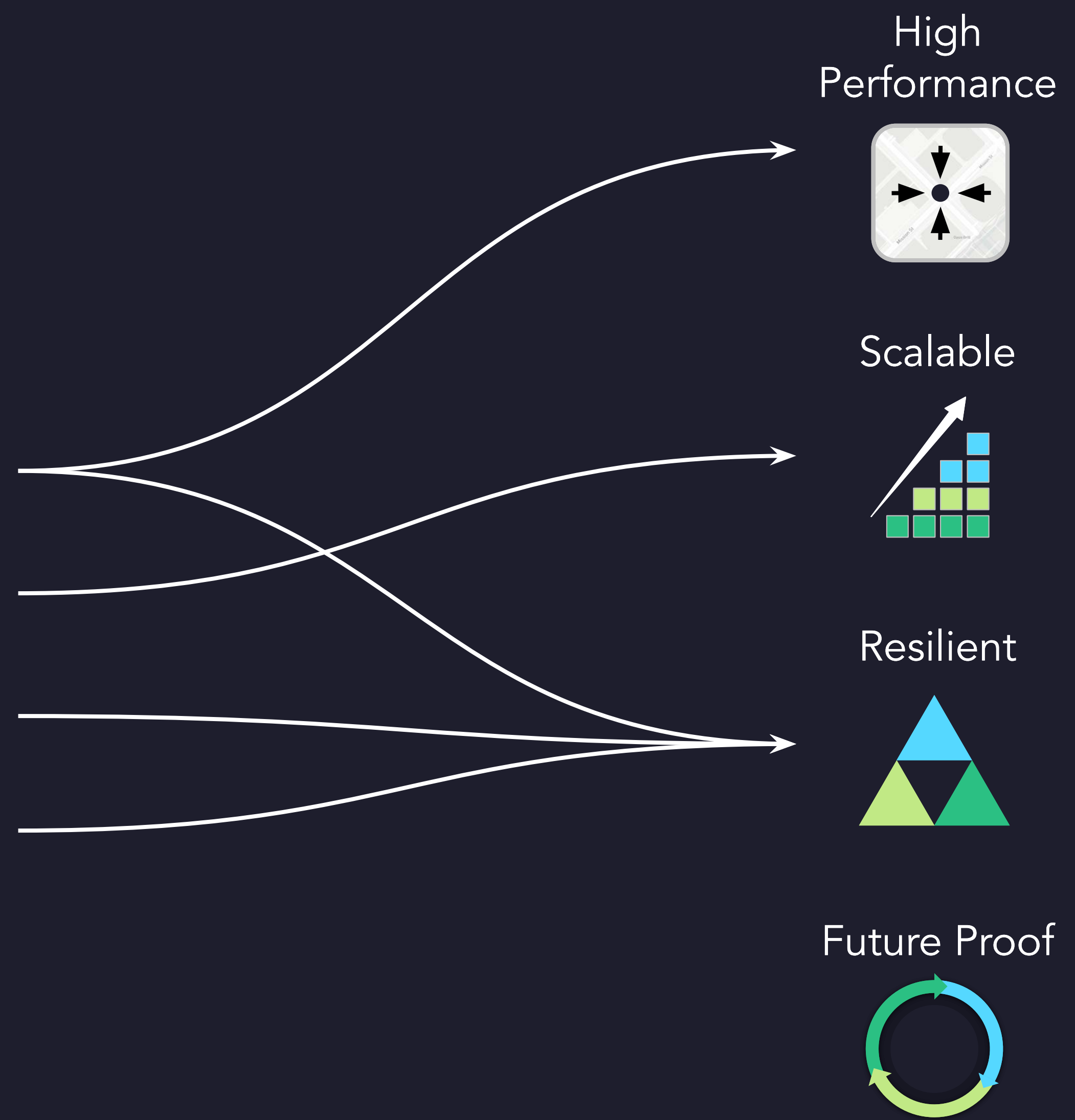




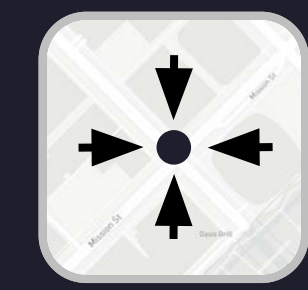
# Small Waves *aka....Higher Frequencies!*



- Compact User Antennas
- Compact Satellite Antennas
- Absolute Frequency Agility
- Different from L-band



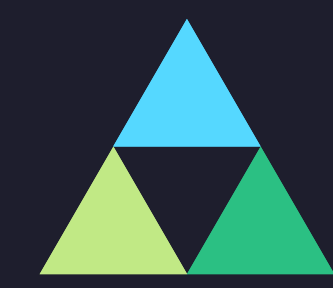
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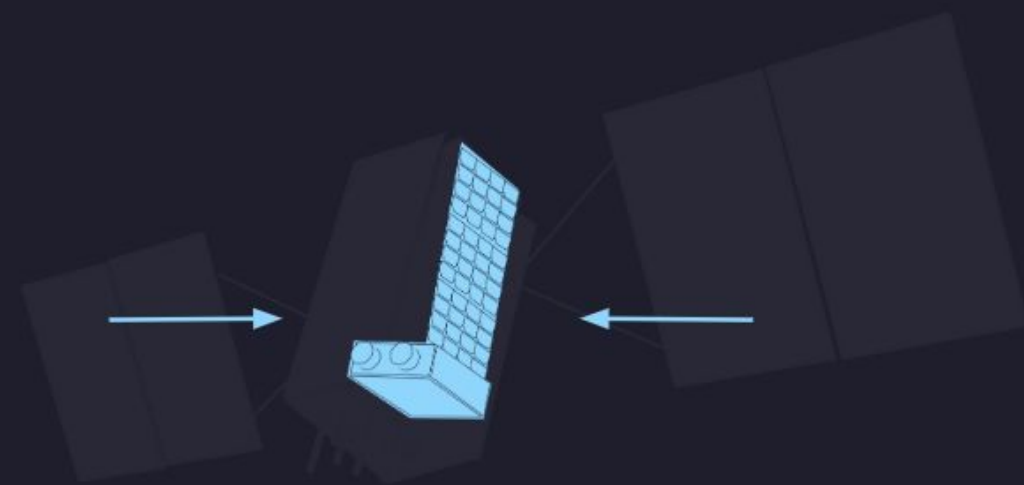




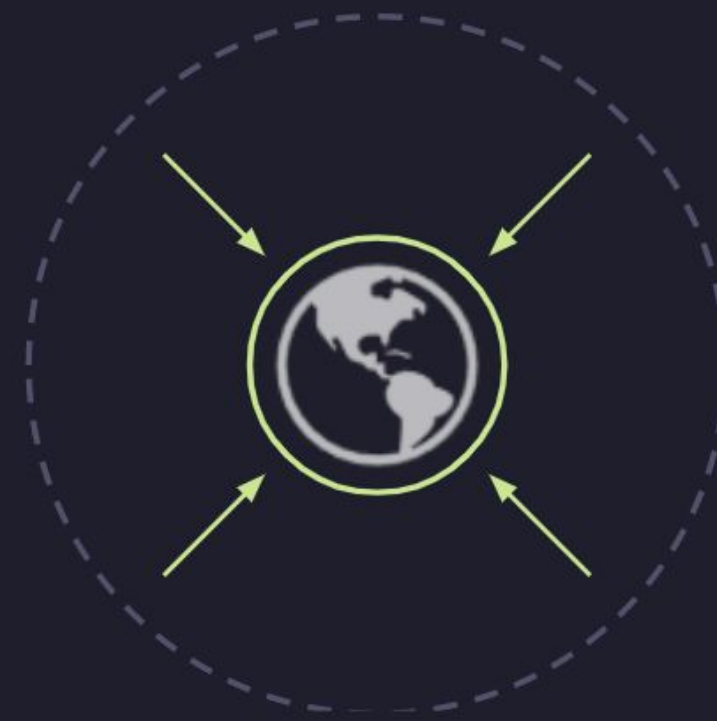
# Key Takeaways on Small Sats, Orbits and Waves

1. High Performance CubeSats Available at Prices Approaching \$200K/Sat
2. Material Difference Between Moderate LEO and Higher LEO Systems
3. Great Performance Opportunities for Small Antennas Above L-band

Small Satellites



Small Orbits



Small Waves





# Recommendations

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1. Grow USG Sponsored Field Test & Demo Days
2. Look Beyond L-band
3. Relax ITAR
4. \*\*\*\* Invest In and Buy Commercial \*\*\*\*



# Summary

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- TrustPoint Company Overview
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# Thank You for Your Time!

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Patrick Shannon, CEO | [patrick@trustpointgps.com](mailto:patrick@trustpointgps.com)

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[www.trustpointgps.com](http://www.trustpointgps.com)