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Deployment Strategies for a Financially Viable Remote Sensing Constellation



MIT Student 1

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Agenda

- Context and Motivation
- Problem Statement
- Methodology
 - ❑ *Modelling Approach*
 - ❑ *Static Case*
 - ❑ *Incorporating Flexibility*
- Results
- Limitations and Assumptions
- Conclusions and Lessons Learned

Space-based Remote Sensing

What is Space-based Remote Sensing?

Obtaining, processing and providing data on terrestrial objects, phenomena and scenes as gathered by imaging payloads onboard space-based assets

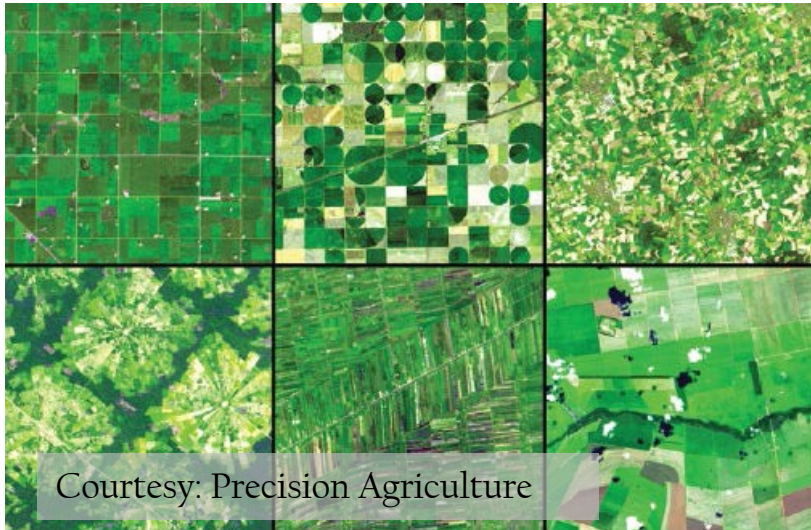
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A New Paradigm: CubeSat Constellations

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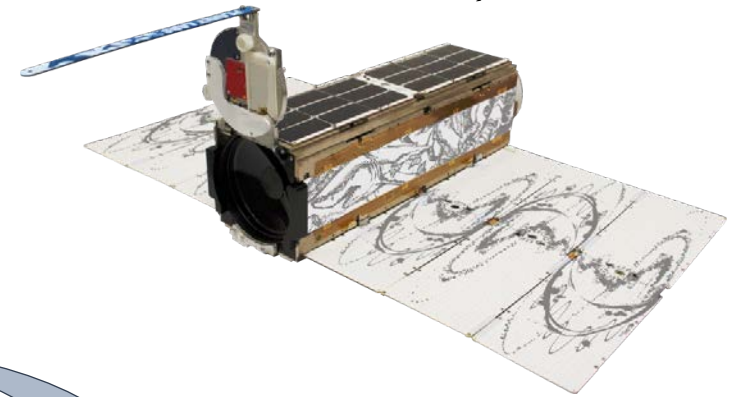
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- ~ 20 ft x 8 ft
- ~ 7000 lbs
- < 1 ft resolution
- \$650,000,000

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- ~ 1 ft x 0.3 ft
- ~ 15 lbs
- ~ 10 ft resolution
- Low cost

Problem Statement

Problem

- Large architectural trade space for constellations of CubeSats
- High-risk, high-reward + uncertainty → decision support required

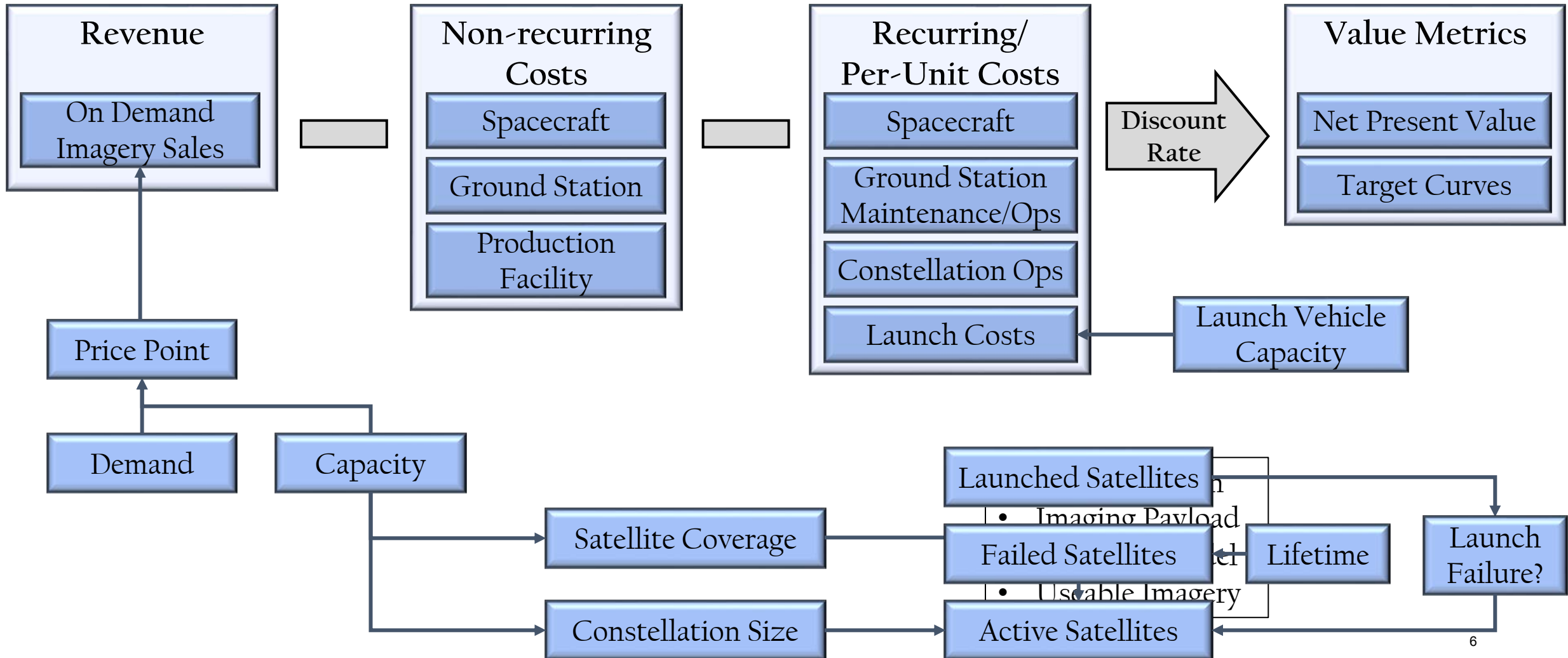
Goal

- Method to explore architecture decisions for deployment strategies responsive to uncertain market and technological conditions

Approach

- Cost-centric (NPV), parametric system model capturing key design decisions and uncertainties (Monte Carlo)
- Respond to uncertainties with flexible decision making

Modeling Approach



Model Output

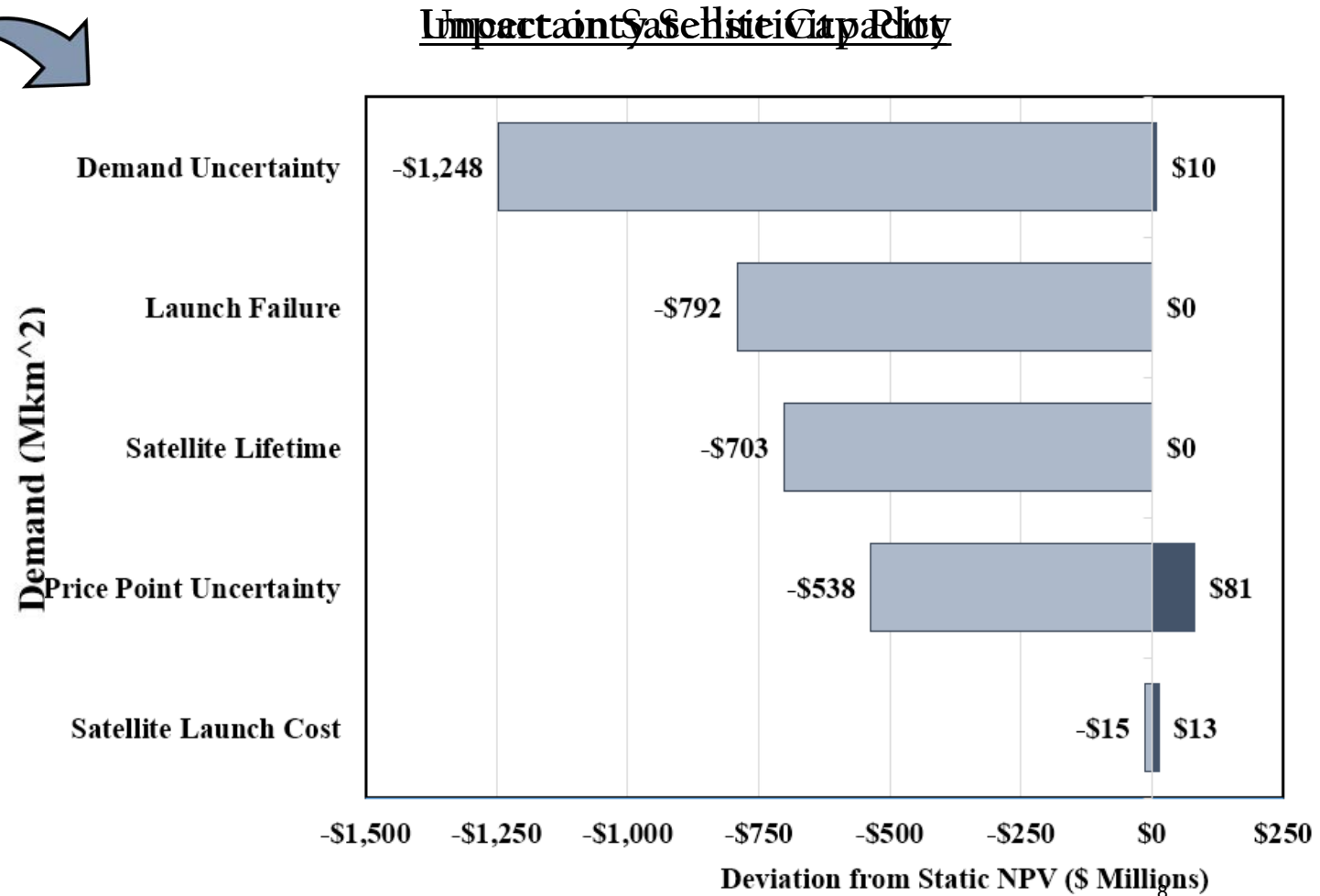
	2018		2023	2027
Demand				
Realized Demand (Mkm ²)	-			
Capacity				
Satellites On-Orbit	0			
Capacity On-Orbit (Mkm ²)	0			
New Satellites to Deploy	10			
Failed Satellites	0			
Revenue				
Met Demand (Mkm ²)	0			
Revenue	\$ -	\$ 166,000,000		
Costs				
Non-Recurring Costs	\$ 112,600,000	\$ -		
Recurring/Per-Unit Costs	\$ 195,600,000	\$ 260,400,000		
Total Satellites Manufactured	10			
Cashflow Analysis				
Net Cashflow	\$ (308,200,000)	\$ (94,400,000)		
Discounted Cashflow	\$ (308,200,000)	\$ (75,400,000)		
Net Present Value	\$ 989,500,000			

Non-Recurring Costs			2023	2027
Satellite Bus Development	\$2,600,000	SSCM (conservative)		
Satellite Imager Payload Development	\$10,000,000	NICM	679	
Ground Station Development	\$50,000,000	SMAD, Ch. 11	60	
Manufacturing Facility	\$50,000,000	SMAD, Ch. 11	664	
			50	
			40	
Recurring Costs				
Ground Facilities Maintenance	\$45,000,000	SMAD, Ch. 11		
Constellation Operations	\$100,000,000	Public (assumed)	664	
Program Management and Systems Engineering	\$15,000,000	SMAD, Ch. 11	\$ 920,000,000	
			\$ -	
			\$ 394,500,000	
Per-Unit Costs				
Satellite Manufacturing	\$3,500,000	SSCM (conservative)	165	
Launch Costs	\$450,000	Public		
			\$ 525,500,000	
			\$ 172,200,000	

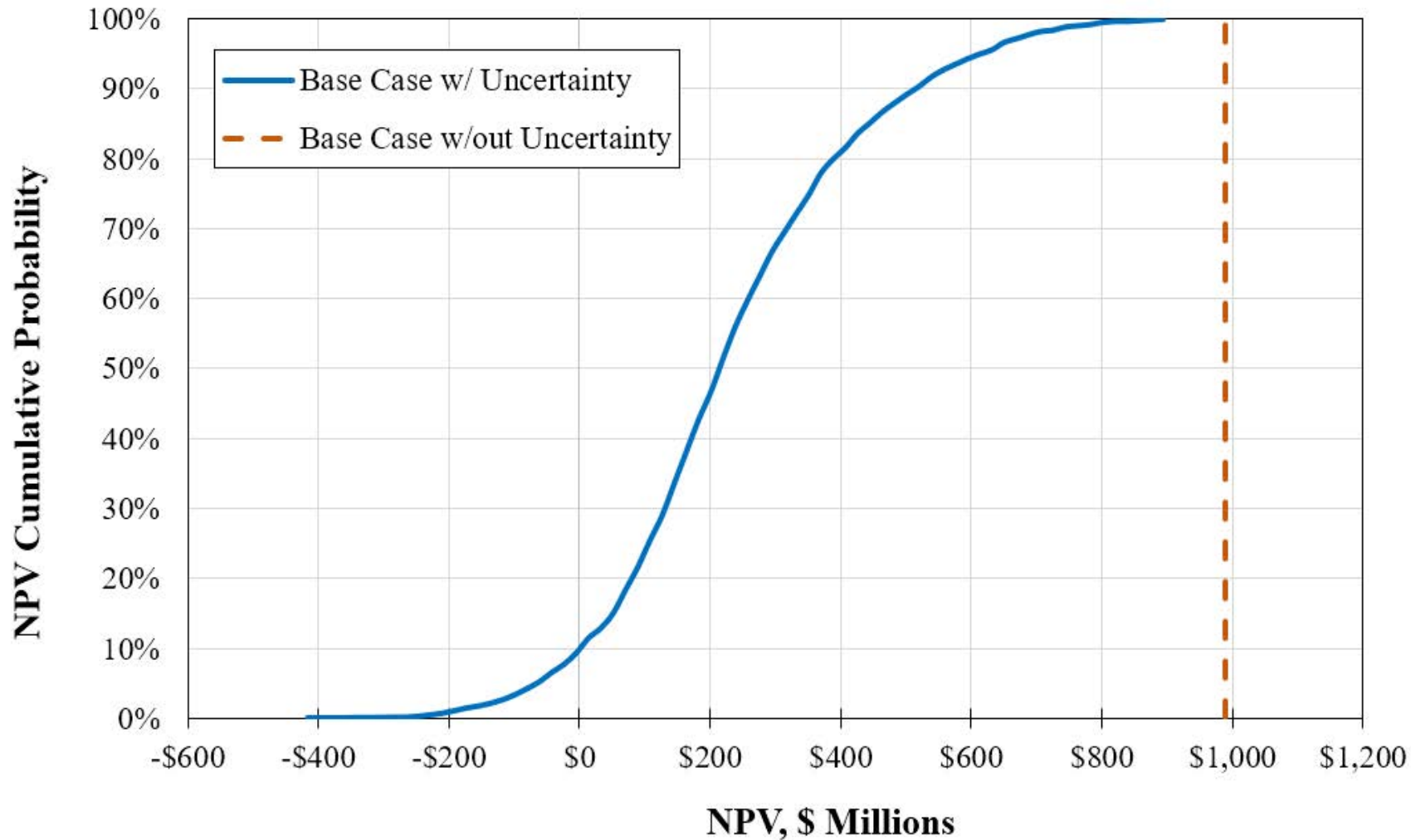
“Base Case” – Static deployment, perfect knowledge

Sources and Impacts of Uncertainty

Uncertain Parameter	Above Nominal	Below Nominal
Demand	30%	30%
Satellite Lifetime	0%	35%
Price-Point	10%	30%
Launch Cost	20%	20%
Launch Failures	5% chance	
Learning Curve Slope	97%, fixed	



Static Case with Uncertainty



Metric	\$, Millions
Maximum NPV	\$960
Minimum NPV	(\$440)
Average NPV	\$230
Value At Risk, P5	(\$70)
Value At Risk, P10	\$0
Value at Gain, P90	\$500
Value at Gain, P95	\$600

Architecting with Flexibility

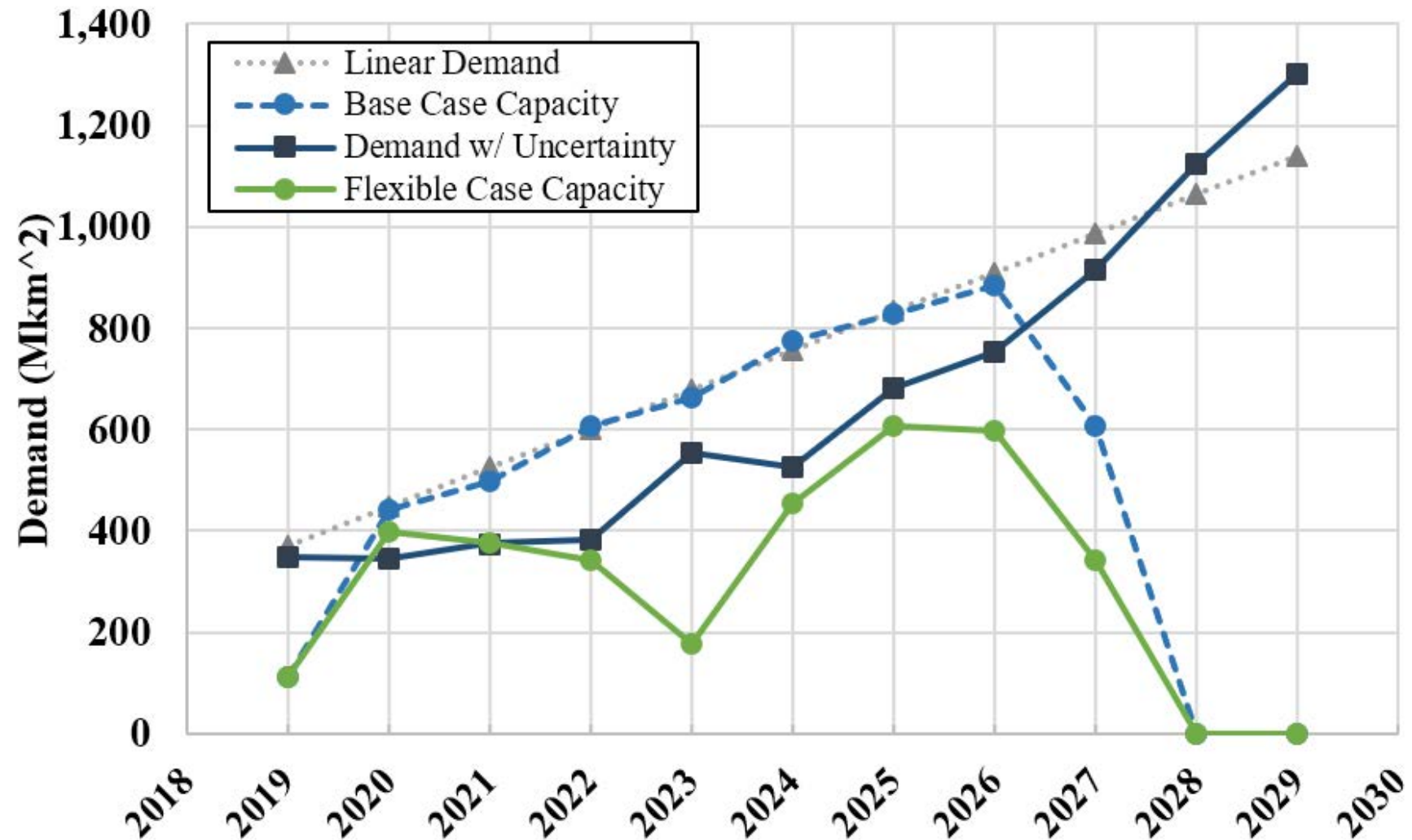
- Address most impactful sources of uncertainty → dynamic response as the future unfolds
 1. Satellite deployment reactive to demand volatility
 2. Launch vehicle flexibility
 3. Improved reliability of CubeSats → improved lifetime

Implementation

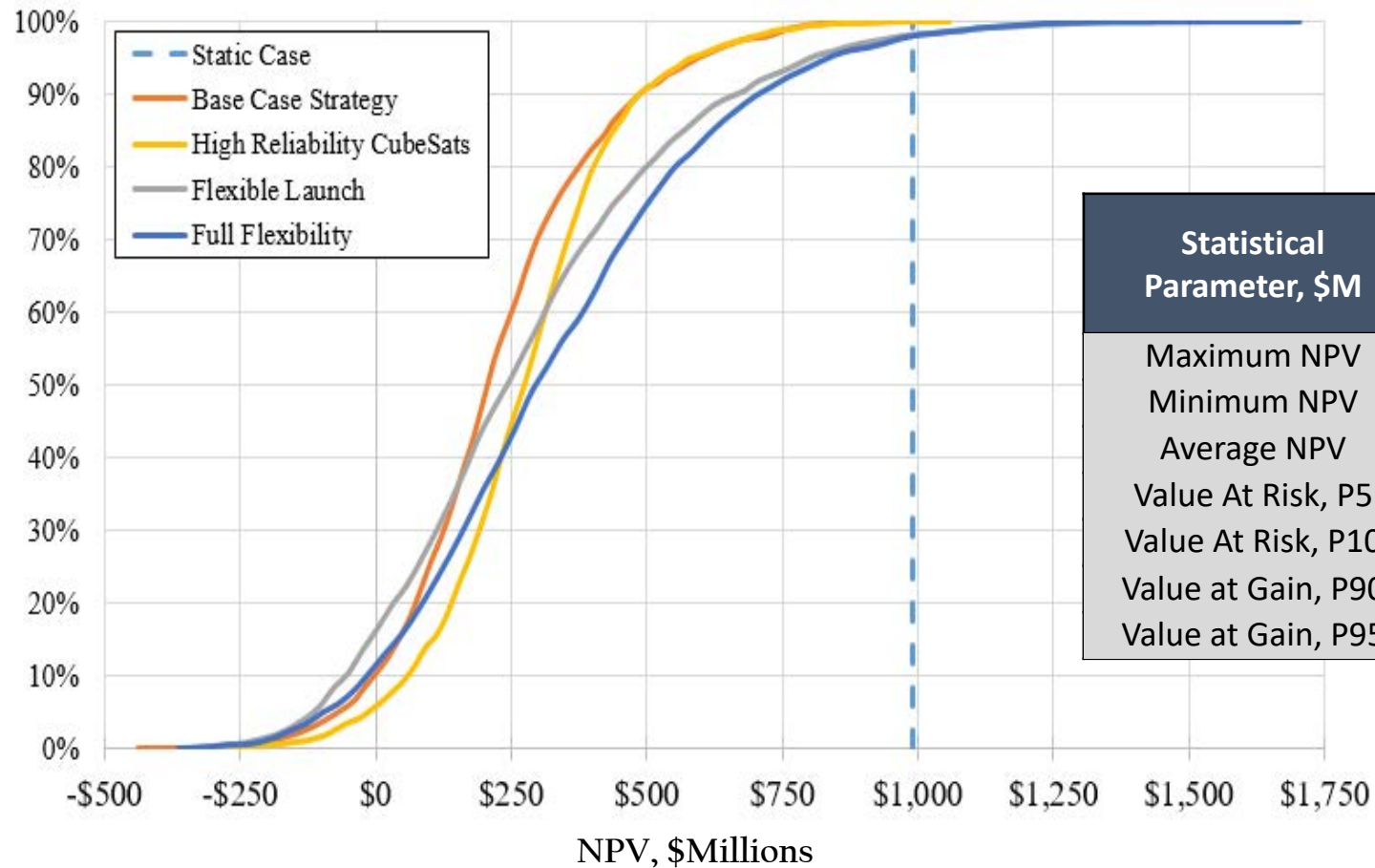
$$X_{flex} = X_{base}(1 + \Delta D\%)$$

If Satellite Lifetime >20% below nominal:
Payload Upgrade = \$10 M
Bus Upgrade = \$5 M
Ground Station Upgrade = \$2.5 M
Facility Upgrade = \$12.5 M
Else
Do Nothing

Flexibility and Demand Uncertainty



Flexibility under Uncertainty



Statistical Parameter, \$M	Base Case	High Reliability CubeSats	Flexible Launch	Full Flexibility (High Reliability + Flexible Launch)
Maximum NPV	\$960	\$1,050	\$1,500	\$1,700
Minimum NPV	(\$440)	(\$350)	(\$350)	(\$360)
Average NPV	\$230	\$275	\$240	\$300
Value At Risk, P5	(\$70)	(\$10)	(\$120)	(\$100)
Value At Risk, P10	\$0	\$60	(\$50)	(\$10)
Value at Gain, P90	\$500	\$480	\$680	\$700
Value at Gain, P95	\$600	\$580	\$800	\$840

Assumptions and Limitations

- Emphasis should be on process/methodology, figures are for demonstration only
- Assumptions/limitations to consider:
 - ☐ Linear marginal coverage model
 - ☐ Simple satellite capacity model
 - ☐ SSCM over-costing CubeSat development and production
 - ☐ Pricing and demand models by extrapolation
 - ☐ Fixed launch vehicle capacity

Conclusion

- Avoid the Flaw of Averages! Look at Uncertainties!
- Large costs, significant technical overhead, long deployment timelines make modeling space systems a complex endeavor
 - Simplicity of model should frame understanding of results (qualitative over quantitative fidelity)
- A perfectly designed technical architecture can still fail financially
 - Iridium constellation - \$5 B deployment cost, sold for \$25 M after bankruptcy (“Build large...then look for customers”)
- Flexible and responsive plan found to be better than a rigid one
 - However, choice of particular flexibility strategy dependent on stakeholder priorities

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