
Courtesy: Planet, *PlanetScope*

Deployment Strategies for a Financially Viable Remote Sensing Constellation

MIT Student 1

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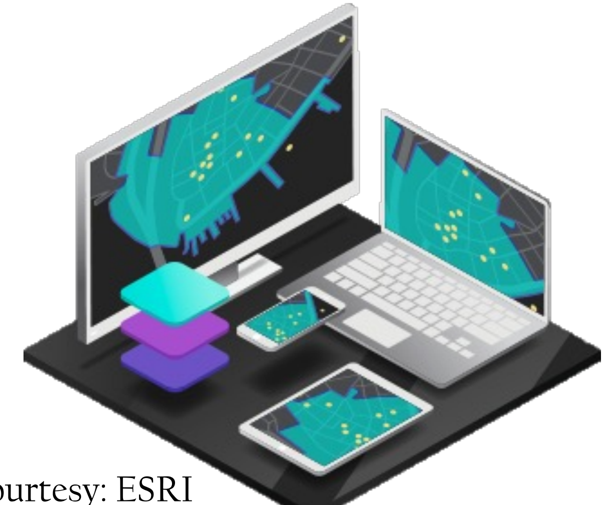
Agenda

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

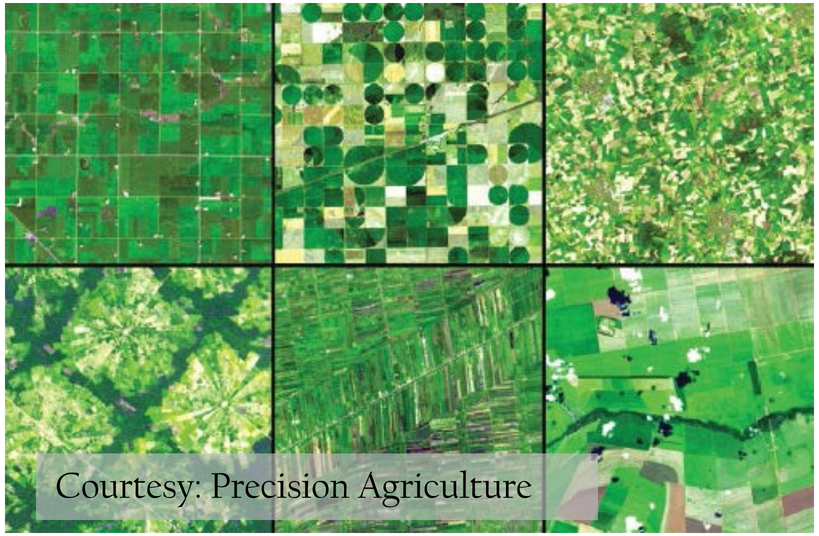
Space-based Remote Sensing



Courtesy: ESRI

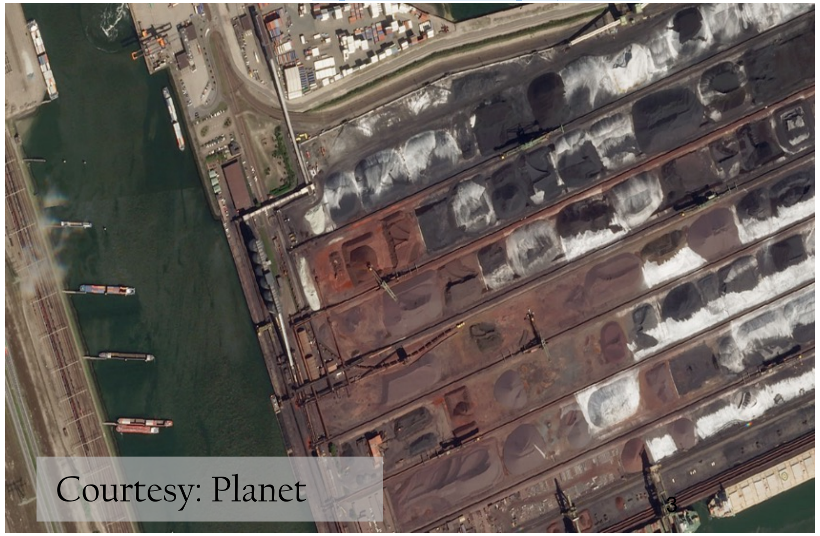
<u>What is Space-based Remote Sensing?</u>

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



Courtesy: Precision Agriculture

Courtesy: Earth Imaging Journal

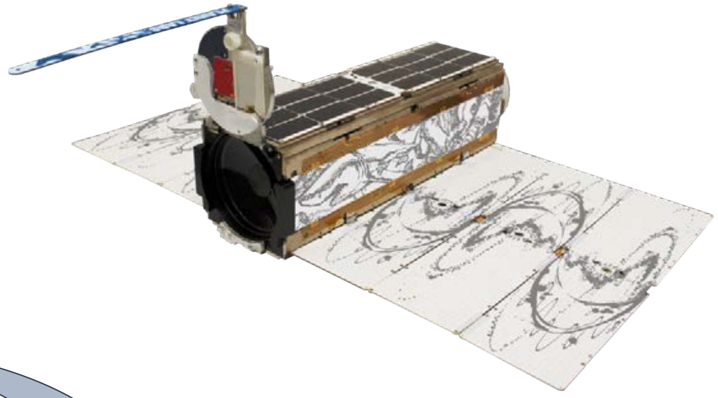


Courtesy: Planet

A New Paradigm: CubeSat Constellations

Courtesy: Maxar

Courtesy: Planet



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

- ~ 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

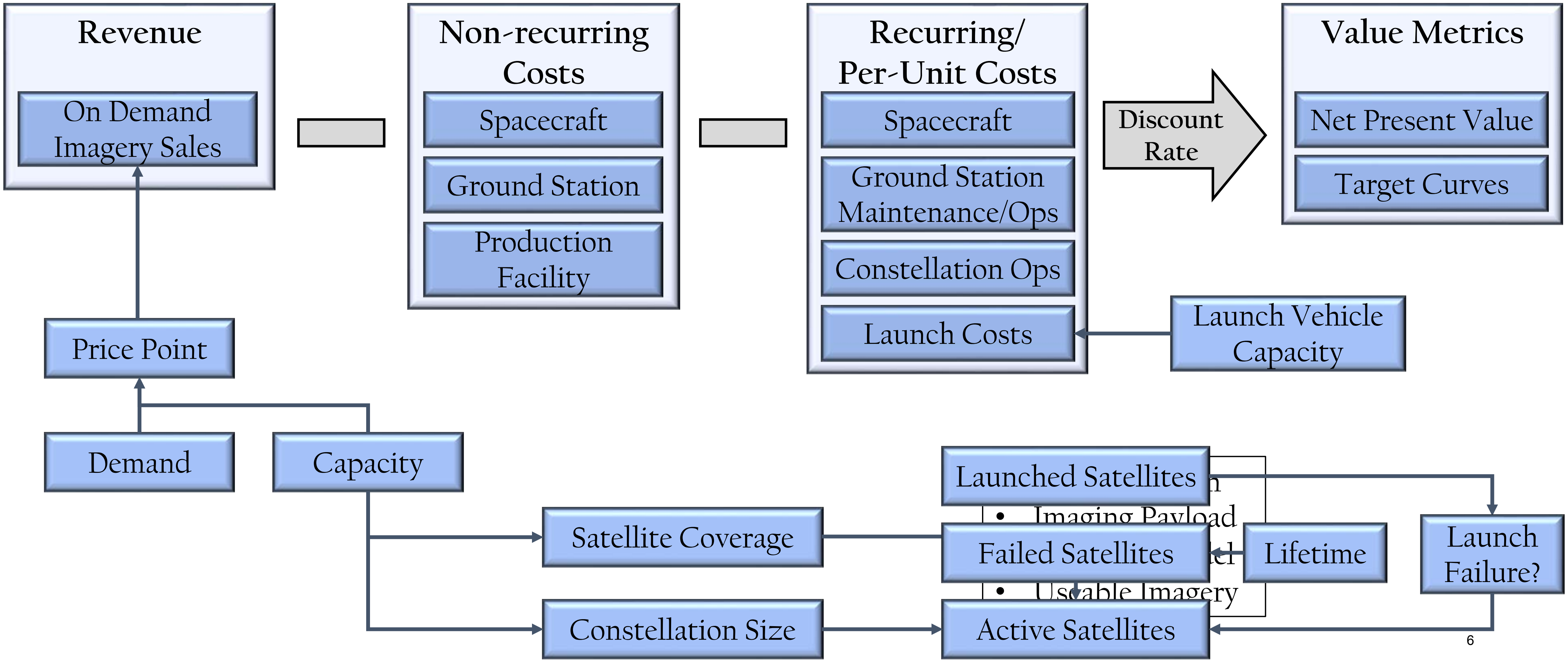
Goal

- 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

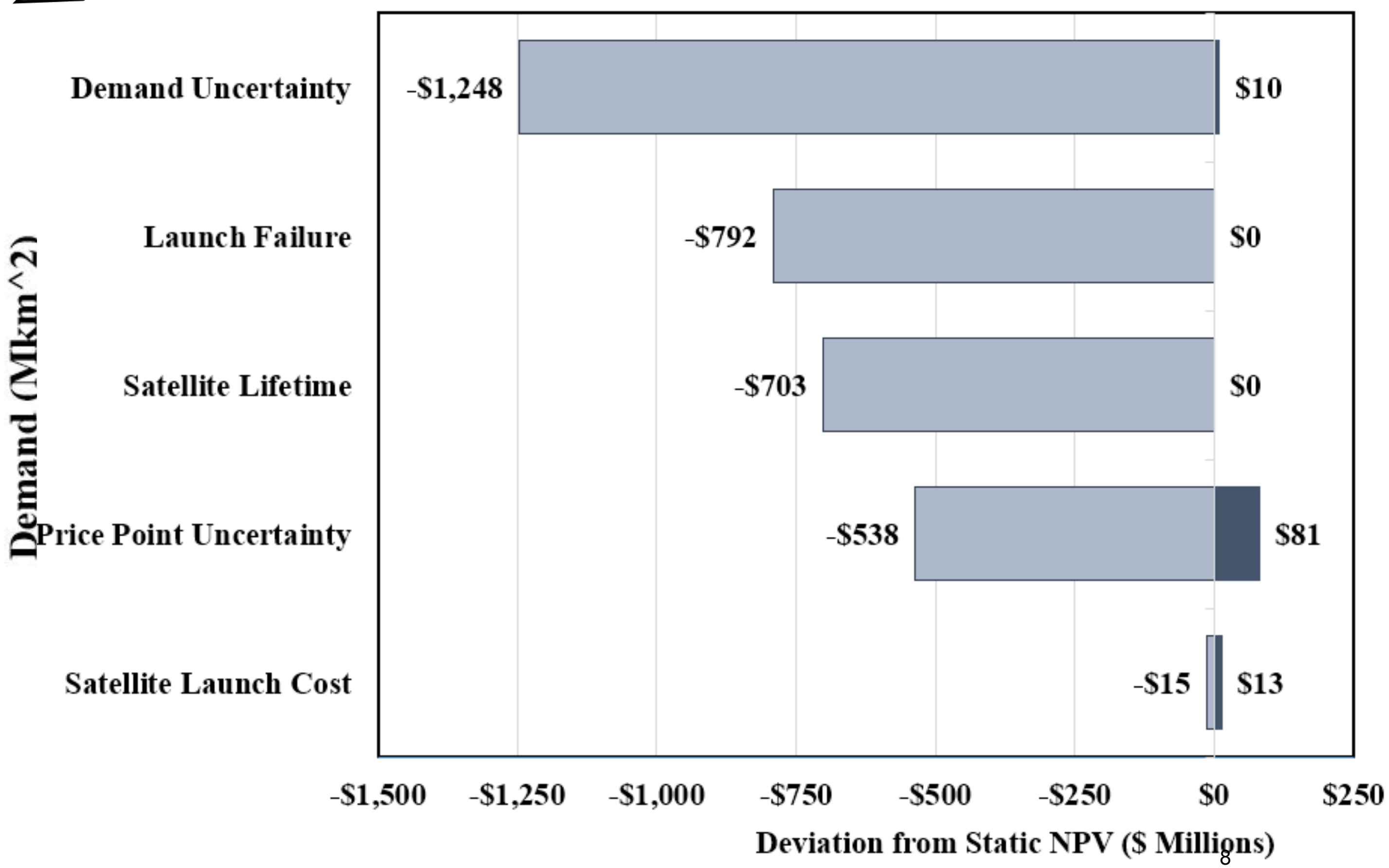
	2018		2023	2027
Demand				
Realized Demand (Mkm^2)	-		679	
Capacity				
Satellites On-Orbit	0		60	
Capacity On-Orbit (Mkm^2)	0		664	
New Satellites to Deploy	10		50	
Failed Satellites	0		40	
Revenue				
Met Demand (Mkm^2)	0		664	
Revenue	$ -	$ 166,(	$ 920,000,000	
Costs				
Non-Recurring Costs	$ 112,600,000	$	$ -	
Recurring/Per-Unit Costs	$ 195,600,000	$ 260,4	$ 394,500,000	
Total Satellites Manufactured	10		165	245
Cashflow Analysis				
Net Cashflow	$ (308,200,000)	$ (94,4	$ 525,500,000	
Discounted Cashflow	$ (308,200,000)	$ (75,5	$ 172,200,000	
Net Present Value	**$ 989,500,000**			

Non-Recurring Costs		
Satellite Bus Development	$2,600,000	SSCM (conservative)
Satellite Imager Payload Development	$10,000,000	NICM
Ground Station Development	$50,000,000	SMAD, Ch. 11
Manufacturing Facility	$50,000,000	SMAD, Ch. 11
Recurring Costs		
Ground Facilities Maintenance	$45,000,000	SMAD, Ch. 11
Constellation Operations	$100,000,000	Public (assumed)
Program Management and Systems Engineering	$15,000,000	SMAD, Ch. 11
Per-Unit Costs		
Satellite Manufacturing	$3,500,000	SSCM (conservative)
Launch Costs	$450,000	Public

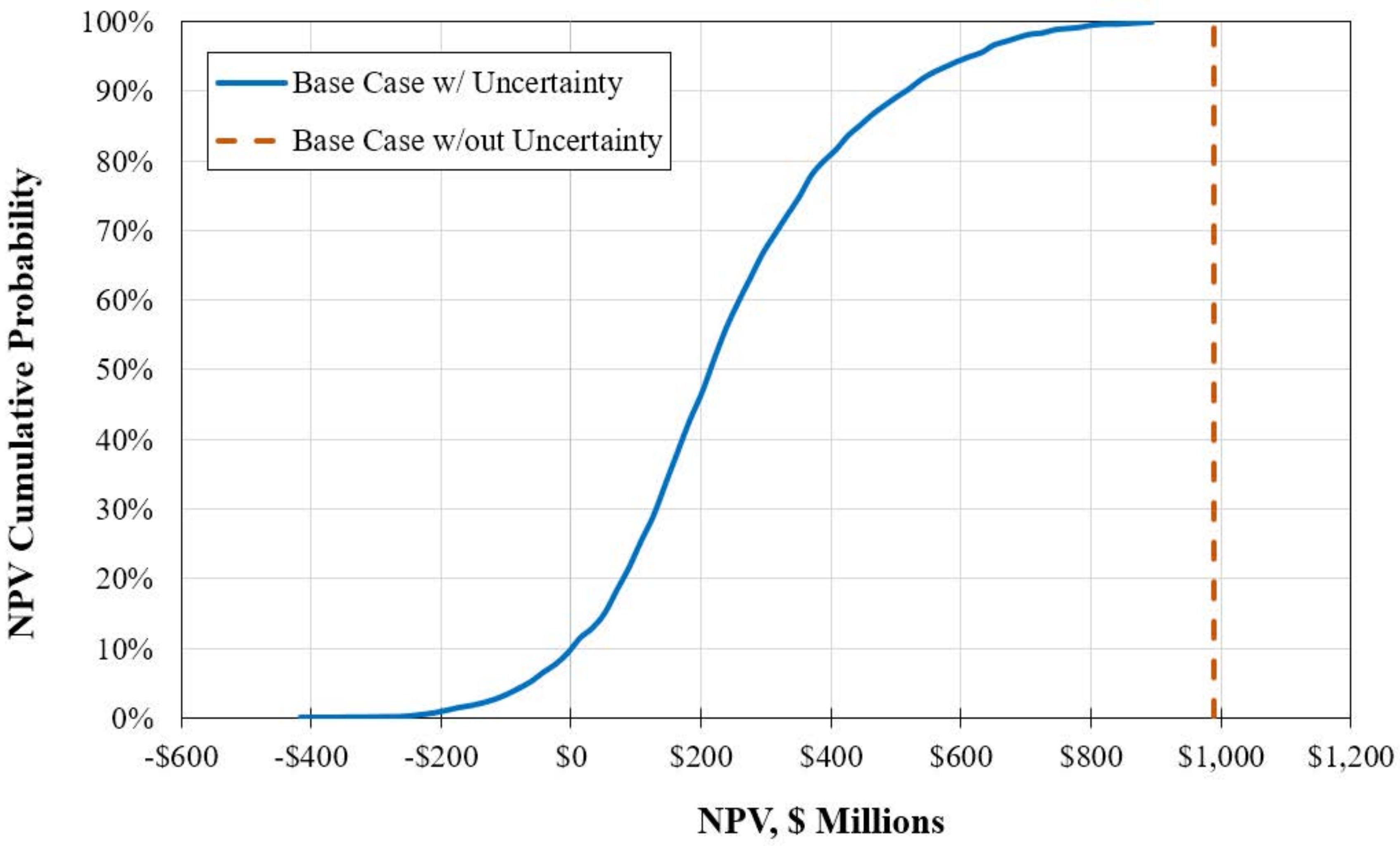
"Base Case" – Static deployment, perfect knowledge

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

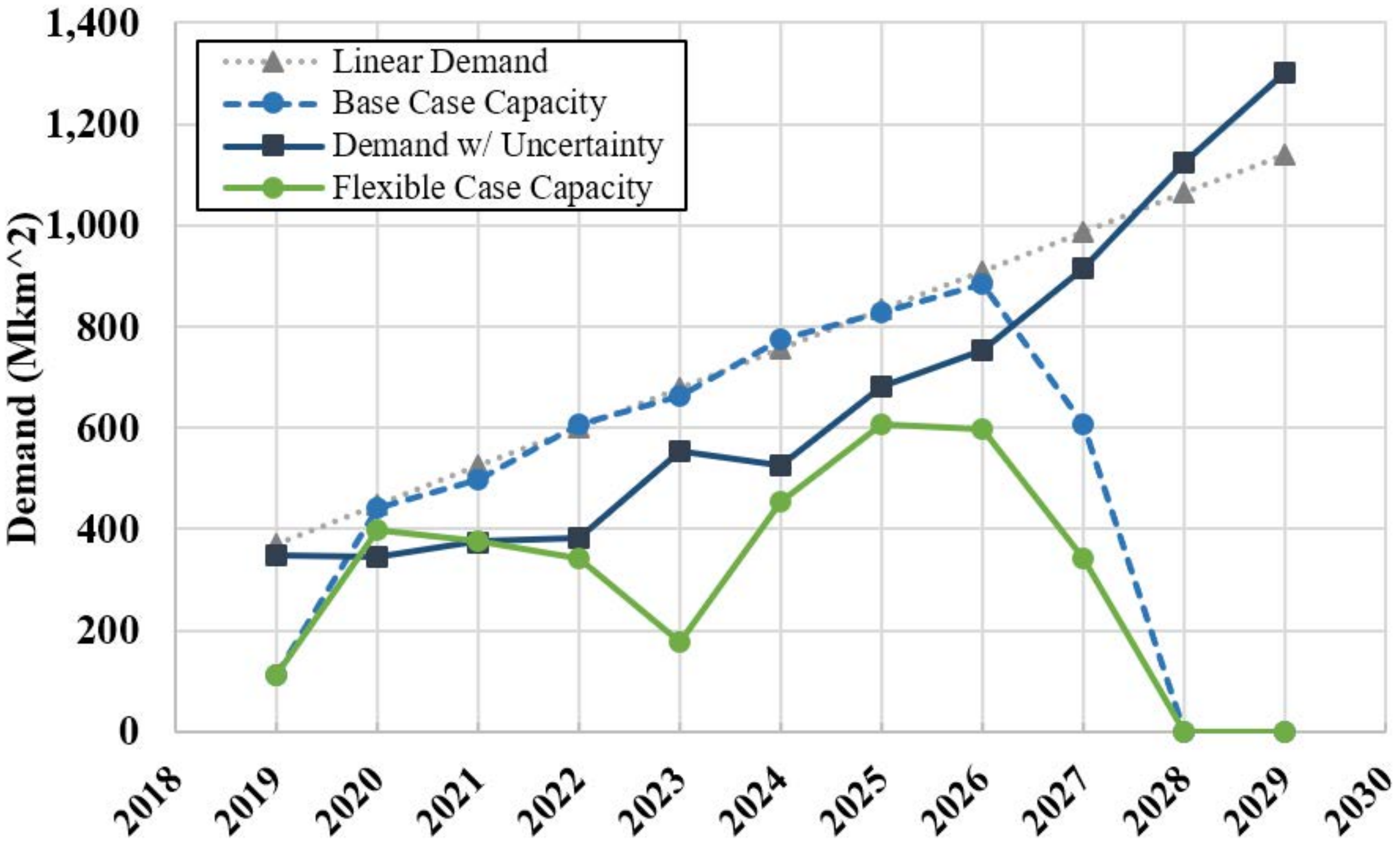
- Address most impactful sources of uncertainty → dynamic response as the future unfolds
  1. Satellite deployment reactive to demand volatility
  2. Launch vehicle flexibility
  3. Improved reliability of CubeSats → improved lifetime

<u>Implementation</u>

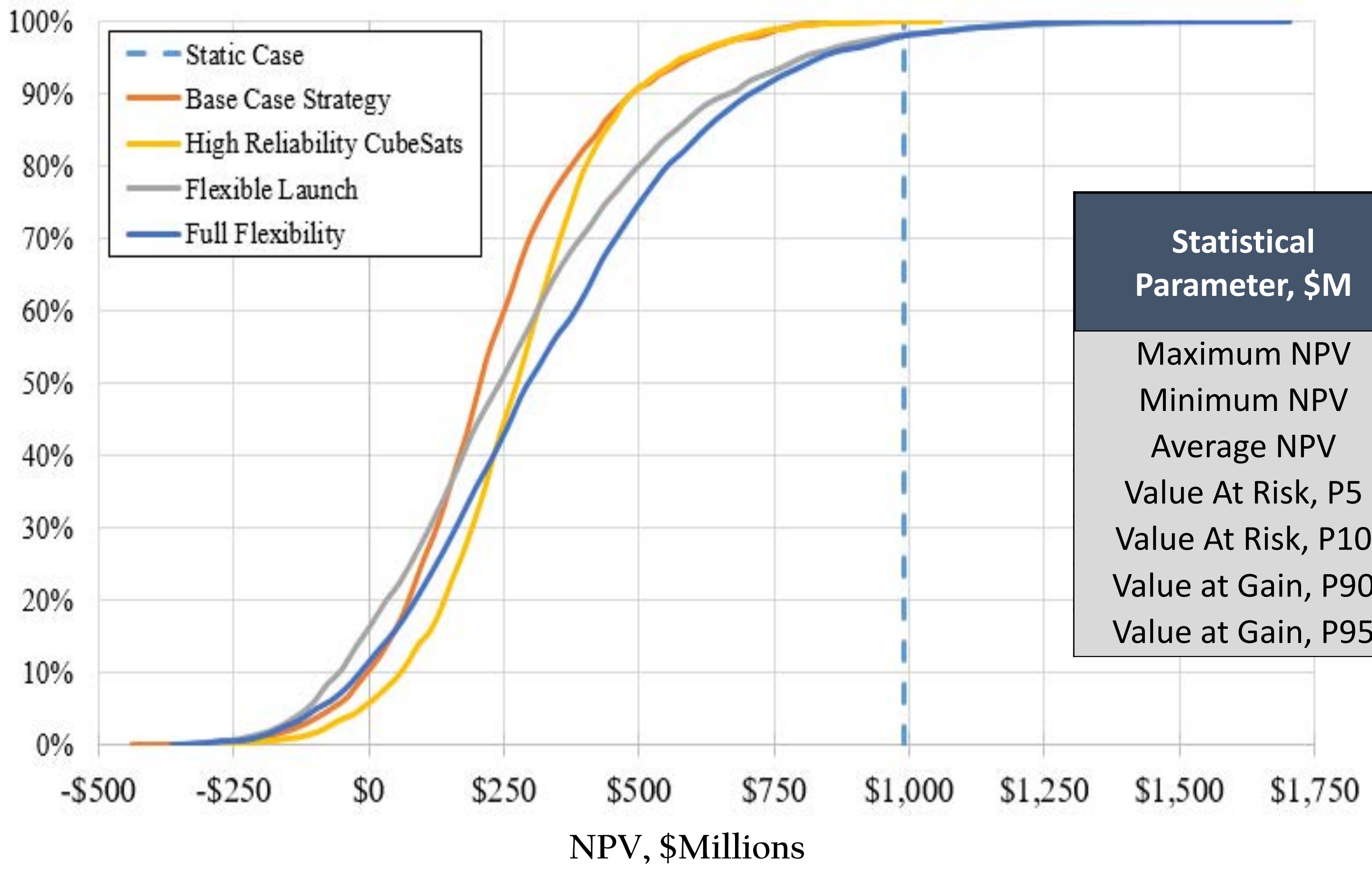
$$X_{flex} = X_{base}(1 + \Delta D\%)$$

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