Wide Area Motion Imagery

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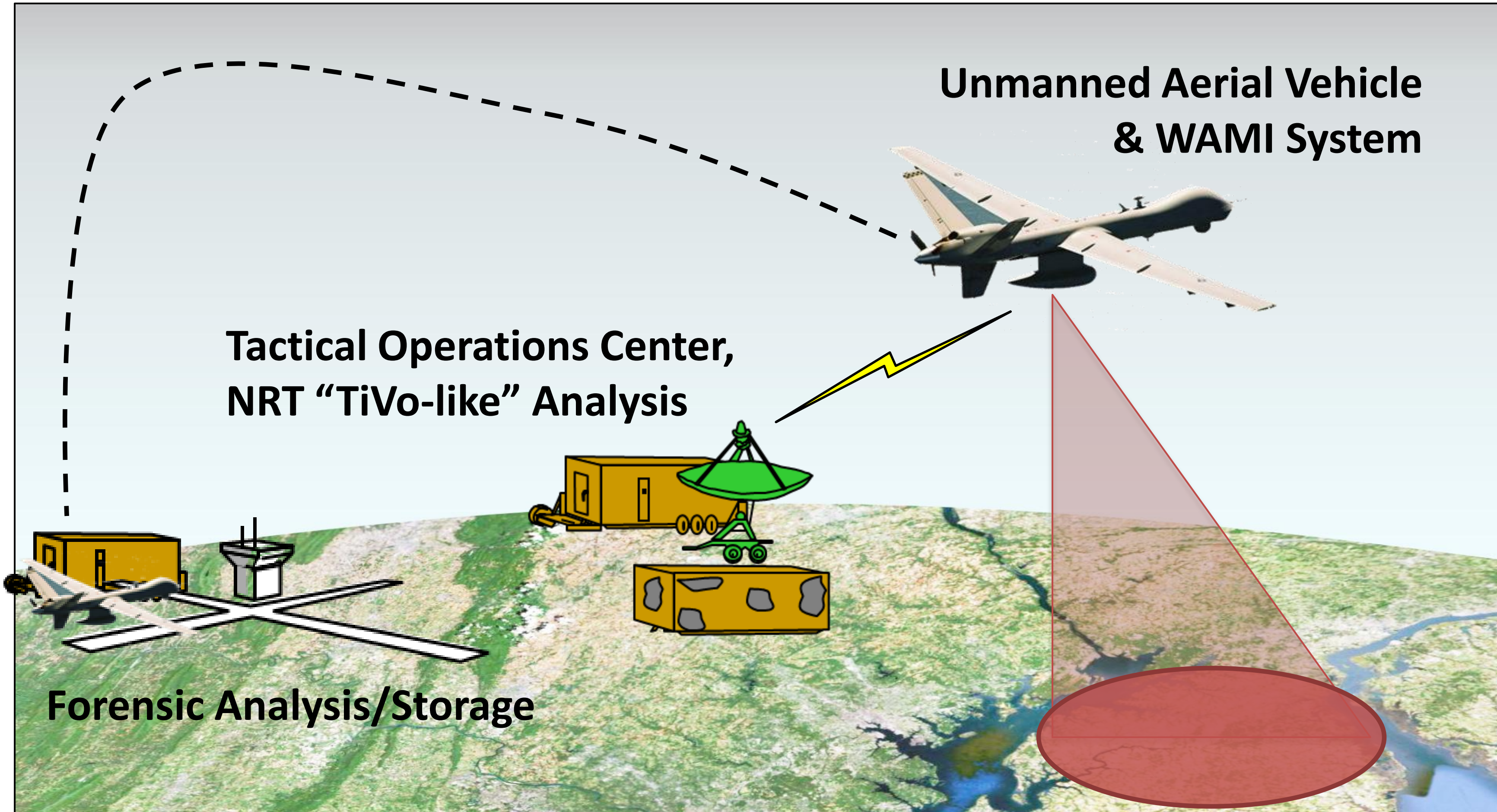
Agenda

- Background
- Problem Definition
- Approach
- Conceptual Design Results
- Performance Analysis Results
- Trade-Off Analysis Results
- Conclusion

Background

- Wide Area Motion Imagery (WAMI) systems drive combat operations by finding and fixing targets
- Bring persistence, precision, and unprecedented situation awareness by identifying low signature targets and providing real-time intelligence to troops on the ground or at home
- Typically mounted on small aircraft, helicopters, balloons, or UAVs to allow a bird's eye-view of ground operations
- Key Attributes:
  - Weight
  - Geospatial Resolution (Ground Sampling Distance (GSD) (meters/pixel)
  - Temporal Resolution (Frame Rate) (Frames/Second or Hz)
  - Processing Power
  - Storage
  - Area of Coverage (Field of View (FoV))

High Level Operational Concept



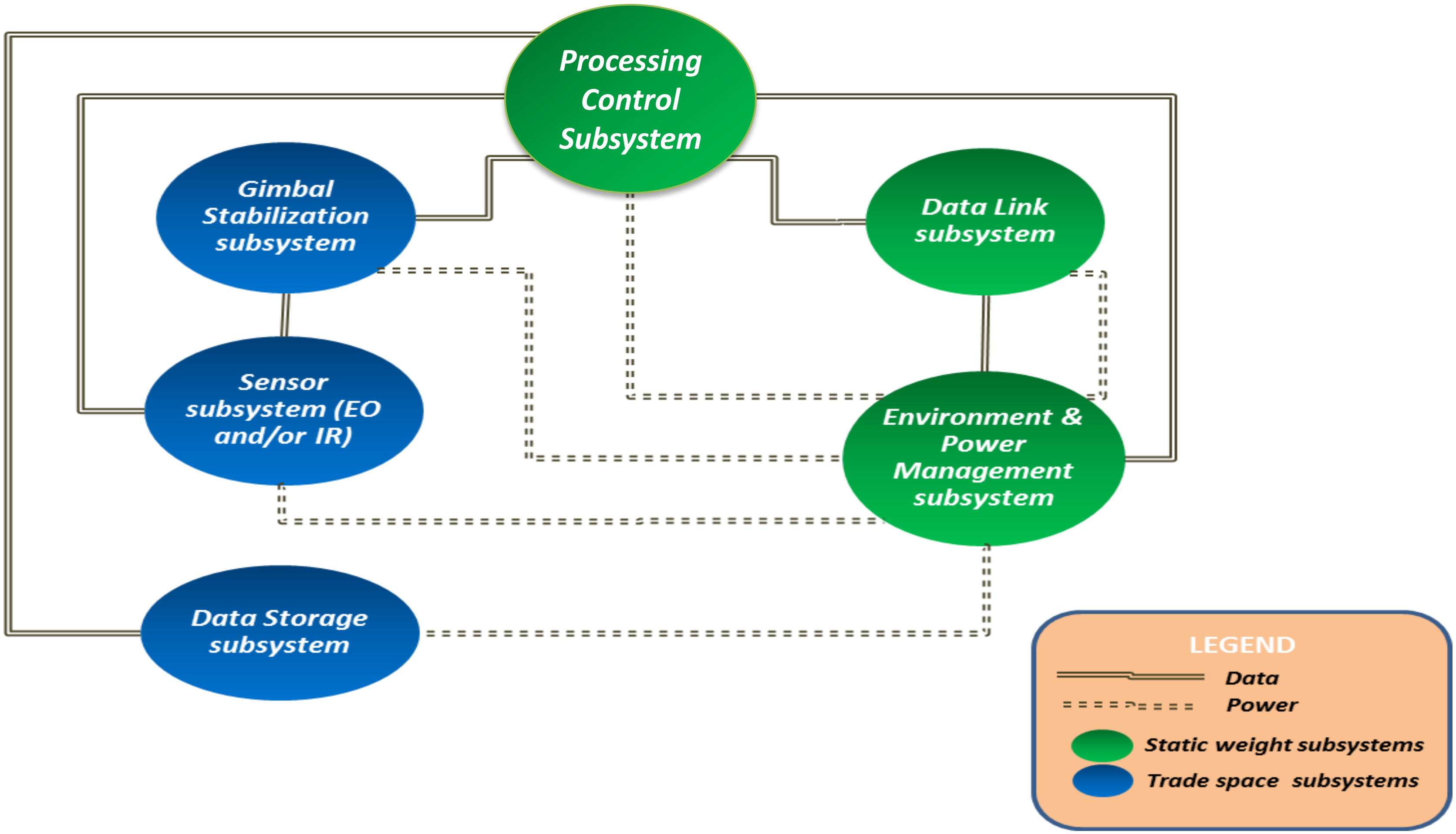
Problem Definition

- Of the WAMI sensors fielded today, there is not a solution compatible to be fielded on current platforms such as the Air Force’s MQ-1 Predator, Army’s MQ-1C Grey Eagle or future platforms such as the Air Force’s Aurora’s Orion.
- The payload weight limit for each of these platforms is approximately 500lbs which is significantly less than current WAMI systems.
- The challenge is to find a WAMI solution that is “good enough” within the 500lb threshold.
- The operational altitude is 20,000 ft and it must be able to detect dismounts (~75% of the demand)
  - EO: GSD ~0.2m/pixel
  - IR: GSD ~0.7m/pixel

Approach

- Conceptual Design – Decompose the system, research historic data and perspective trends, and assess opportunities to reduce the weight
- Performance Analysis – Model performance for each alternative and understand the impacts that weight reductions have on performance
- Trade-off Analysis – Determine solutions that deliver the greatest value with respect to performance

Conceptual Design – Subsystems

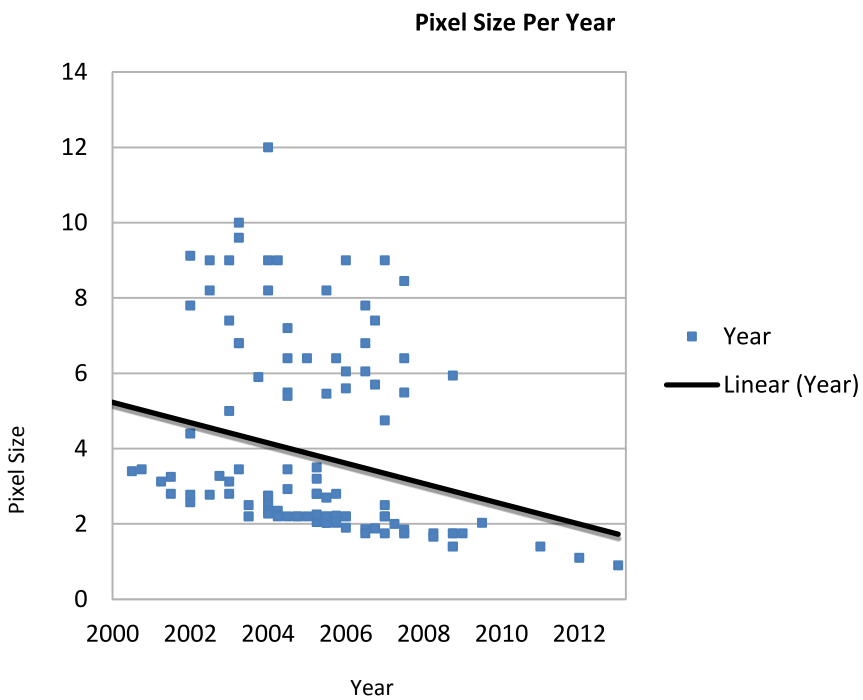


Conceptual Design - Gimbal

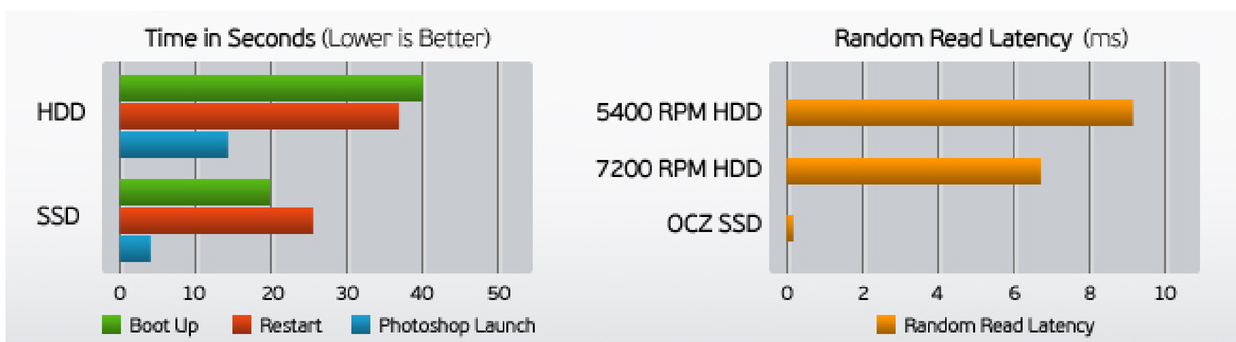
- A gimbal at its most basic is a pivoted support that allows the rotation of an object about a single or multiple axis.
- Current WAMI Sensor technology requires gimbals mounted in or on airborne platforms.
- Gimbals that are primarily used on airborne platforms are for stabilization and steering (two – six axis gimbals)

Conceptual Design - Sensor

- EO and IR sensors weigh 100 – 200 lbs each on current systems
- Shrinking pixels means smaller focal length and focal plane for same resolution (linear relationship)
- Expect to reach 0.9 μm in 2013
- Pixel reduction by 50% has the potential to reduce the weight of the sensor by up to 40%
  - IR sensor weight reduction = 40%
  - EO sensor weight reduction = 30%



Conceptual Design - Storage

	HDD	**SSD**
Weight	1.7 lb.	0.17 lb.
Cost	Class dependent	Class dependent
Reliability	Moving parts susceptible to shock/damage	Non-mechanical design, less heat
Performance		

Conceptual Design
Alternative Selection Requirements

- The system shall be less than 500lbs.
- The sensor subsystem shall be able to detect dismounts at an operational altitude of 20,000ft.
- The gimbal subsystem alternatives shall support a total sensor weight less than or equal to its own weight.
- The storage subsystem alternatives shall include HDD and SSD media that are readily available in the current market
- The storage subsystem alternatives shall include HDD and SSD media that are projected to be readily available in the 2013/2014 market
- The storage subsystem alternatives should include HDD and SSD media that are projected to have an acceptable impact on the total system cost.

Conceptual Design
Alternative Selection

- Weight-reducing alternatives were selected for each of the subsystems
- Resulted in 320 different combinations of WAMI alternatives

Gimbal Size (in)	Weight (lbs)
26	144
25	135
23	120
21	103
18	79

EO Sensor Pixel Width (μm)	Weight (lbs)
0	0
1.32	76
1.1	70
0.9	64

IR Sensor Pixel Width (μm)	Weight (lbs)
0	0
1.32	68
1.1	60
0.9	52

Storage (GB)	Weight (lbs)
3000 HDD	1.7
6000 HDD	1.7
500 SSD	0.17
750 SSD	0.17

Performance Analysis
"Good Enough"

- Performance values selected from fielded systems and future mission needs
- Resulted in 3645 different combinations of WAMI performance requirements.

EO GSD (m/pixel)	IR GSD (m/pixel)	EO FoV (km)	IR FoV (km)	EO Frame Rate (frames/sec)	IR Frame Rate (frames/sec)	Mission Duration (hr)
						12
0.2	0.7	6	6	2	1	24
0.15	0.65	8	8	5	2	48
						72
0.1	0.6	10	10	8	4	96

* Most desirable

Performance Analysis – Storage

- Required storage capacity calculated for each performance combination
- Storage weight determined for each performance combination

$$(1)\ Ground\ Sampling\ Distance\ (GSD) = \left(\frac{PixelWidth}{FocalLength}\right) * Range$$

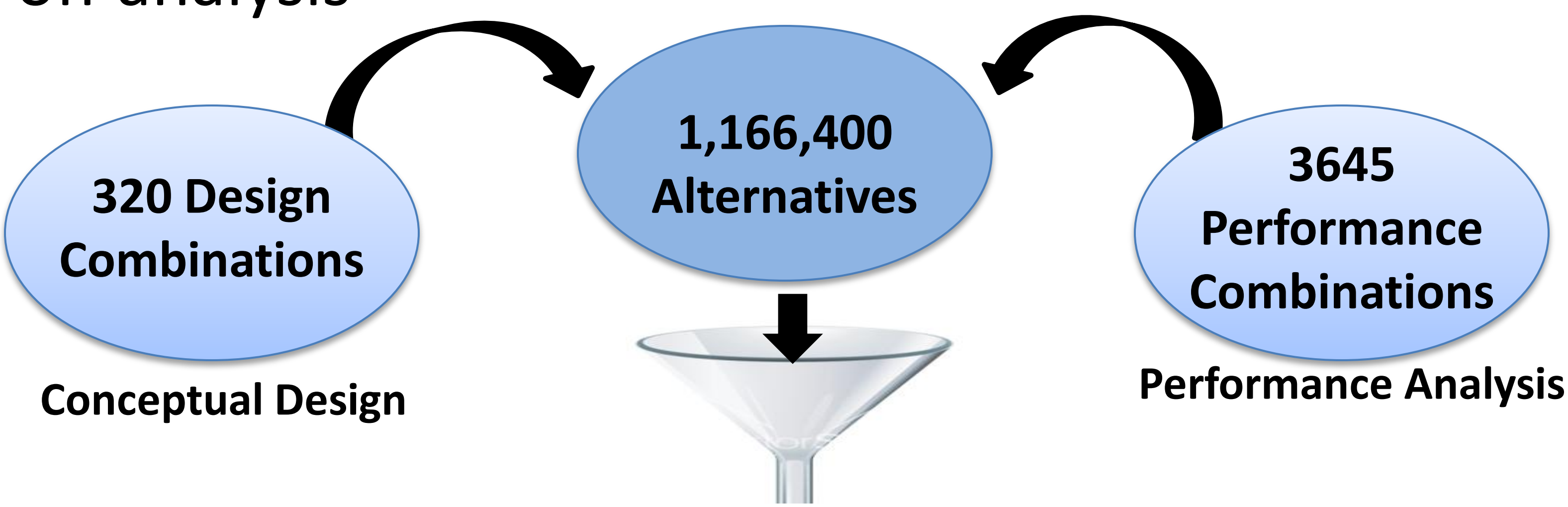
$$(2)\ Sensor\ Length = 2 * Focal\ Length * \tan\left(\frac{1}{2} Angle\ of\ View\right)$$

$$(3)\ Resolution = \left(\frac{SensorLength}{PixelWidth}\right)^2$$

$$(4)\ Storage = Size\ Constant * Resolution * Frame\ Rate * Mission\ Duration$$

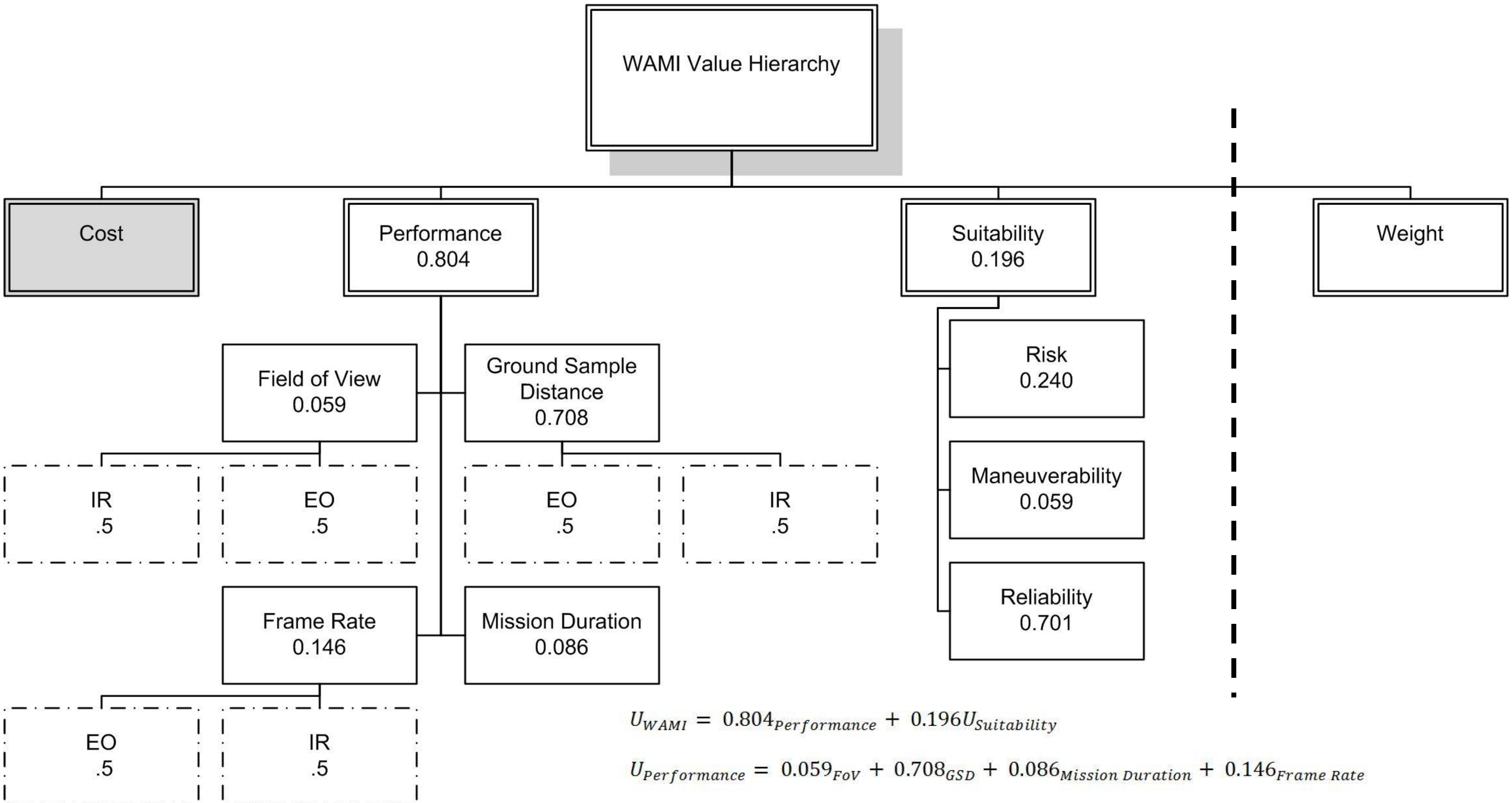
Performance Analysis Results

- Synthesis yielded 1,166,400 <u>total alternatives</u>, BUT
  - 207,256 exceed weight threshold (eliminated)
  - 933,418 inadequate sensor-gimbal pairing (eliminated)
  - 72,900 EO only, IR only, or neither (eliminated)
- 111,389 <u>viable alternatives</u> considered for the trade-off analysis



111,389 Viable Alternatives

Trade-Off Analysis



$$U_{WAMI} = 0.804_{Performance} + 0.196U_{Suitability}$$

$$U_{Performance} = 0.059_{FoV} + 0.708_{GSD} + 0.086_{Mission\ Duration} + 0.146_{Frame\ Rate}$$

$$U_{Suitability} = 0.24_{Risk} + 0.059_{Maneuverability} + 0.701_{Reliability}$$

$$U_{FoV} = 0.5_{IR} + 0.5_{EO}, U_{GSD} = 0.5_{IR} + 0.5_{EO}, U_{Frame\ Rate} = 0.5_{IR} + 0.5_{EO}$$

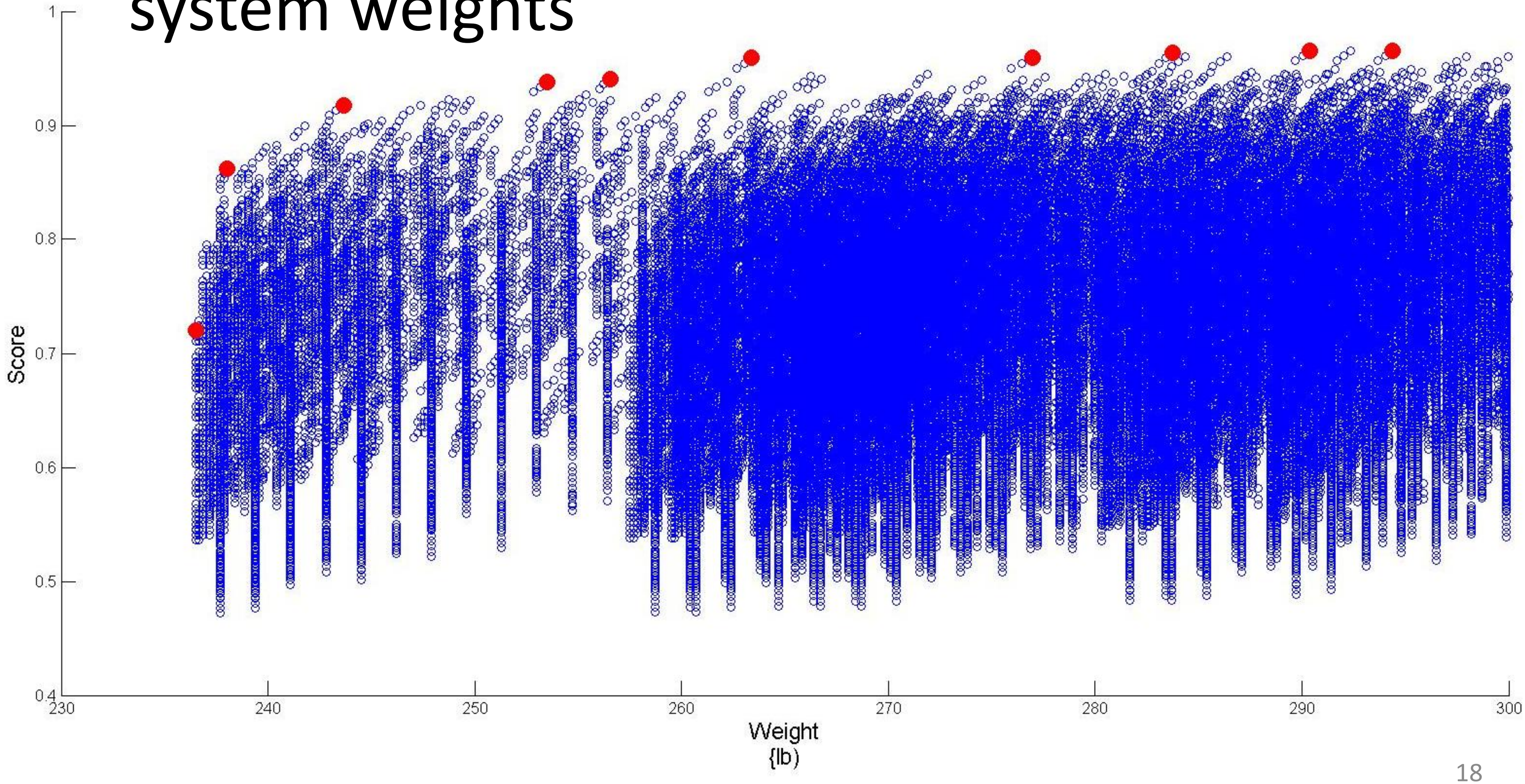
Trade-Off Analysis - Scales

- Symmetrical scales developed to assess each component's impact on risk, reliability, and maneuverability
- Used Min-max normalization to preserve relationships in the data

Risk		
Level	**Impact**	**Likelihood**
1	Minimal	Very Low
2	Low	Low
3	Moderate	Moderate
4	Major	High
5	Unacceptable	Very High

Trade-Off Analysis - Alternatives

- Best value alternatives selected for a variety of system weights



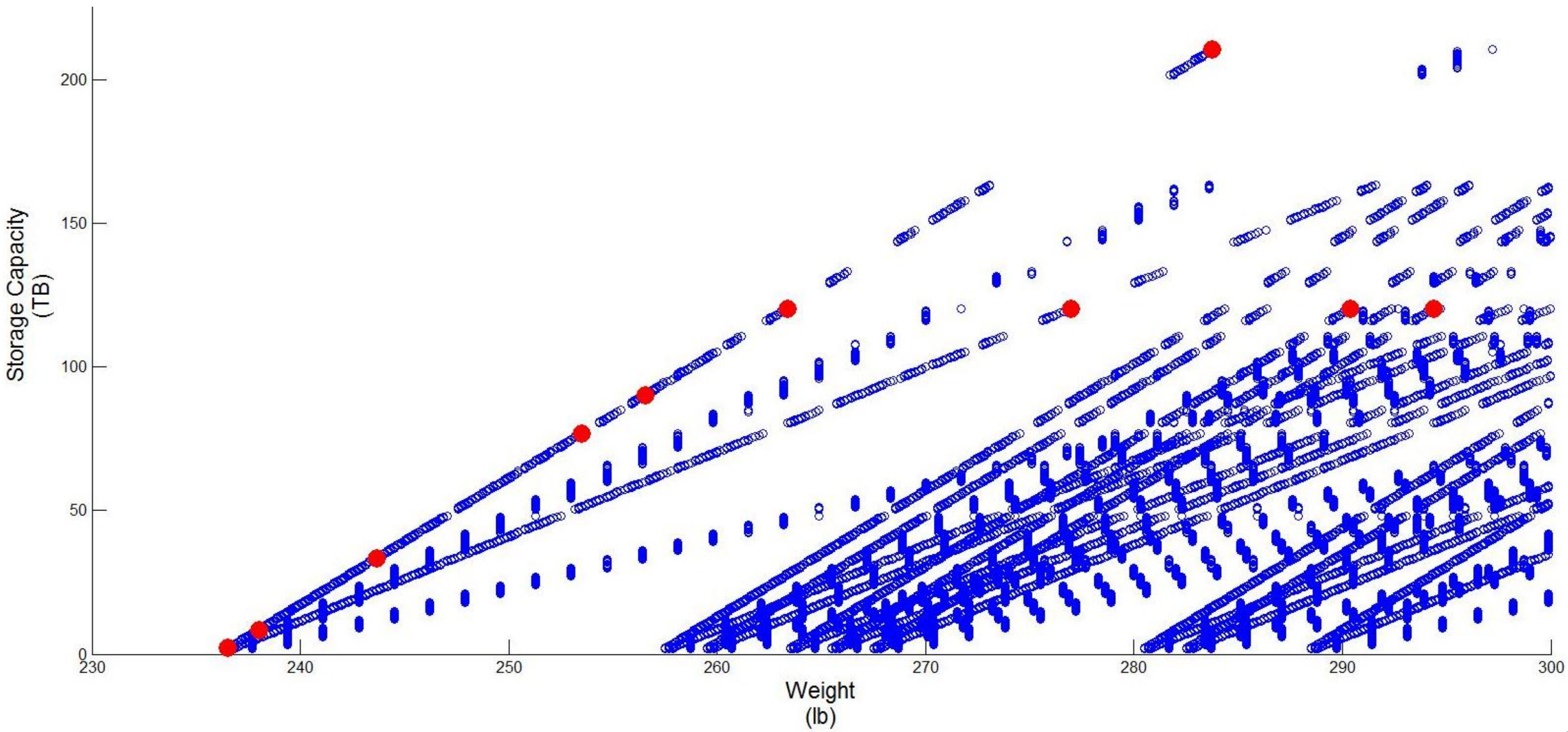
Trade-Off Analysis - Alternatives

Weight	Pixel Width (in)	GSD (m/pixel)	FoV (km)	Resolution (Pixels)	Frame Rate	Gimbal (size)	Storage (GB)	Mission Duration (hr)	Perform. Score	Suitability Score	Total Score
236.51	0.9	0.2	6	9E+08	2	23	750 SSD (x3)	24	0.669936	0.950515	0.679356
	0.9	0.6	6	1E+08	4						
238.04	0.9	0.1	6	3.6E+09	2	23	750 SSD (x12)	24	0.858736	0.950515	0.821523
	0.9	0.6	10	2.78E+08	4						
243.65	0.9	0.1	6	3.6E+09	2	23	750 SSD (x45)	96	0.93245	0.950515	0.87703
	0.9	0.6	10	2.78E+08	4						
253.51	0.9	0.1	6	3.6E+09	5	23	750 SSD (X103)	96	0.959825	0.950515	0.897643
	0.9	0.6	10	2.78E+08	4						
256.57	0.9	0.1	6	3.6E+09	8	23	750 SSD (X121)	72	0.962629	0.950515	0.899754
	0.9	0.6	10	2.78E+08	4						
263.37	0.9	0.1	6	3.6E+09	8	23	750 SSD (X161)	96	0.9872	0.950515	0.918256
	0.9	0.6	10	2.78E+08	4						
276.97	0.9	0.1	6	3.6E+09	8	23	500 SSD (X241)	96	0.9872	0.950515	0.918256
	0.9	0.6	10	2.78E+08	4						
283.77	0.9	0.1	8	6.4E+09	8	23	750 SSD (X281)	96	0.9931	0.950515	0.922699
	0.9	0.6	10	2.78E+08	4						
290.37	1.32	0.1	6	3.6E+09	8	25	750 SSD (X161)	96	0.9872	0.965361	0.920988
	0.9	0.6	10	2.78E+08	4						
294.37	0.9	0.1	6	3.6E+09	8	25	750 SSD (X161)	96	0.9872	0.965361	0.920988
	1.32	0.6	10	2.78E+08	4						

Denotes EO
Denotes IR

Trade-Off Analysis - Storage Capacity

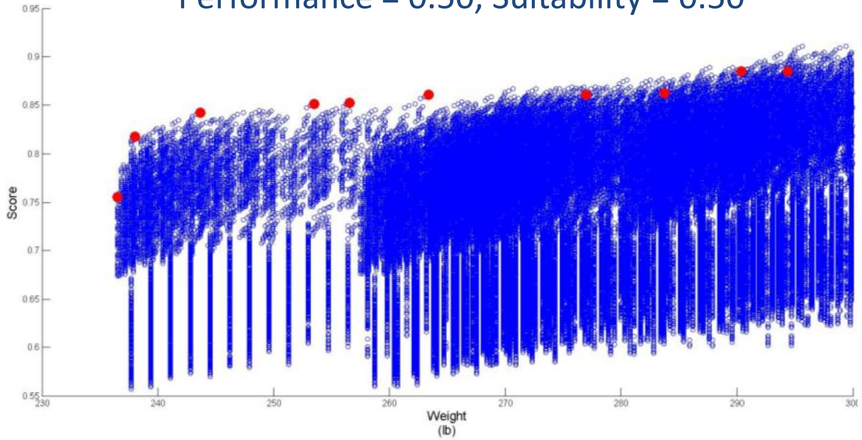
- Both trade-off analysis and performance analysis (exclusive of stakeholder preference) suggest EO FoV as a trade for system weight



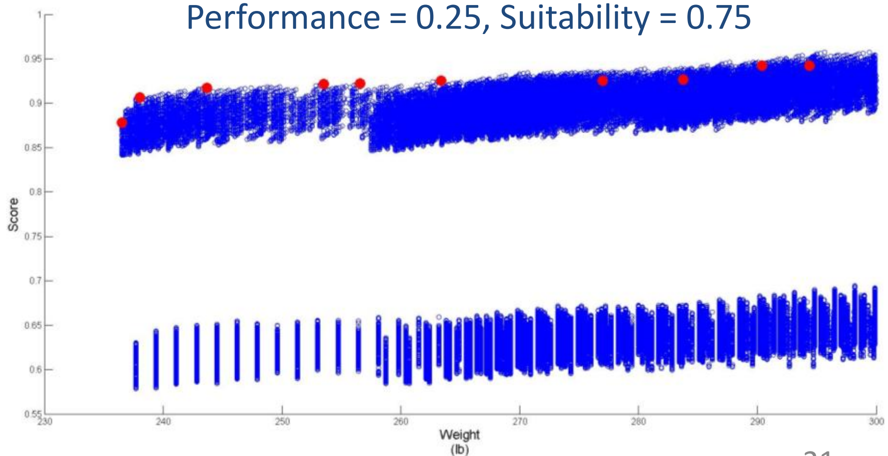
Sensitivity Analysis

- Objective: Understand relationships between inputs and outputs
- Varied stakeholder weights for Suitability and Performance
- Greatest variability for alternatives with greater weight

Performance = 0.50, Suitability = 0.50



Performance = 0.25, Suitability = 0.75



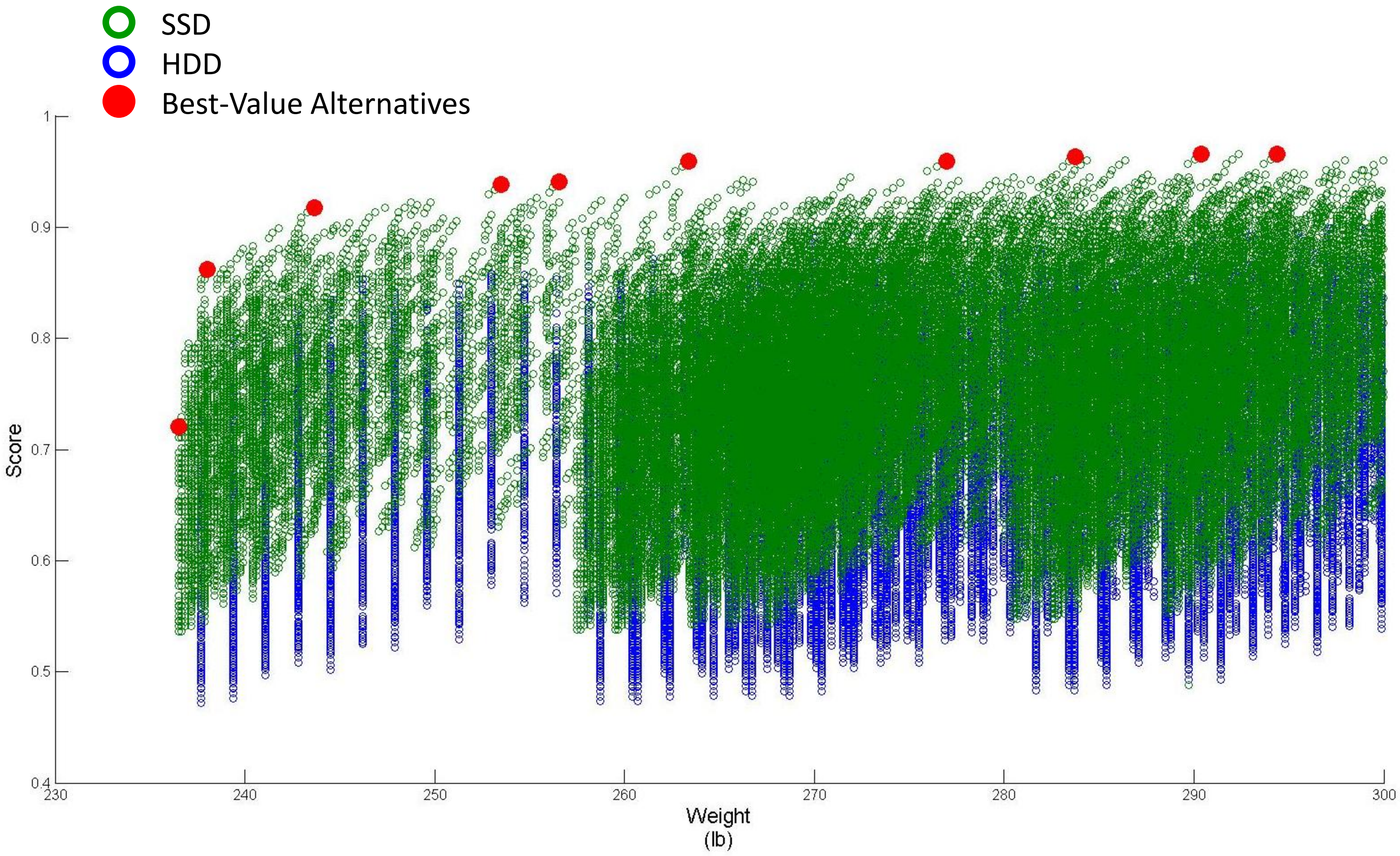
Recommendations / Way Forward

- System requirements can be written with greater specificity
  - Recommend using solid state drives
  - Redefine "good enough" -- Consider trades and adjust least/most desirable performance measures
- Analysis to determine the maximum performance achievable with a single alternative or set of technologies
- Size and power need consideration, since they too can greatly impact design considerations
  - Additional requirements to narrow the set of alternatives; redo tradeoff/sensitivity analysis with different objectives
- Reassess key assumptions, minimally to understand their impact
  - Storing only 2% of mission data
  - A weight reduction of 30%/40% for the sensor with a pixel width reduction of 50%

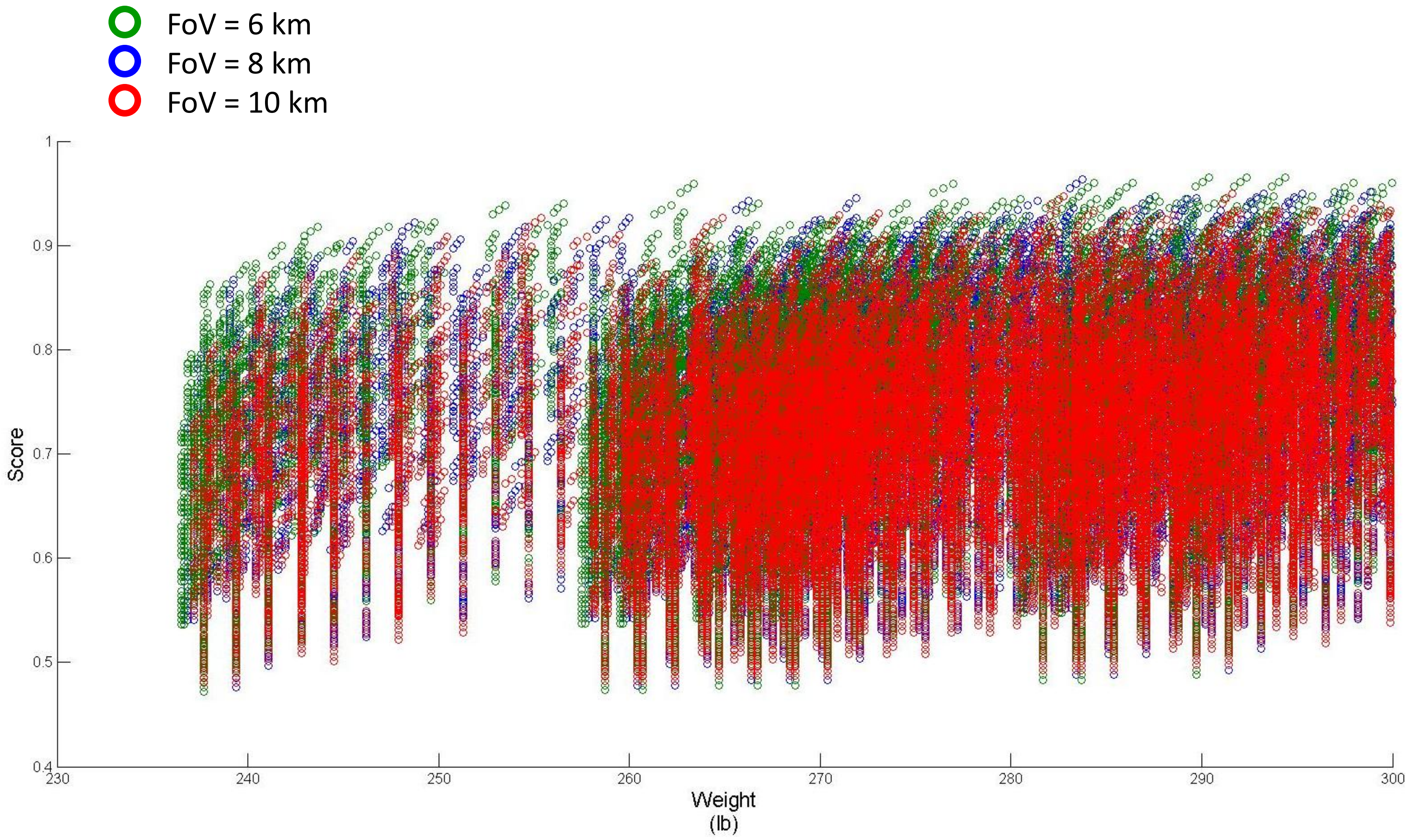
Questions?

Backup

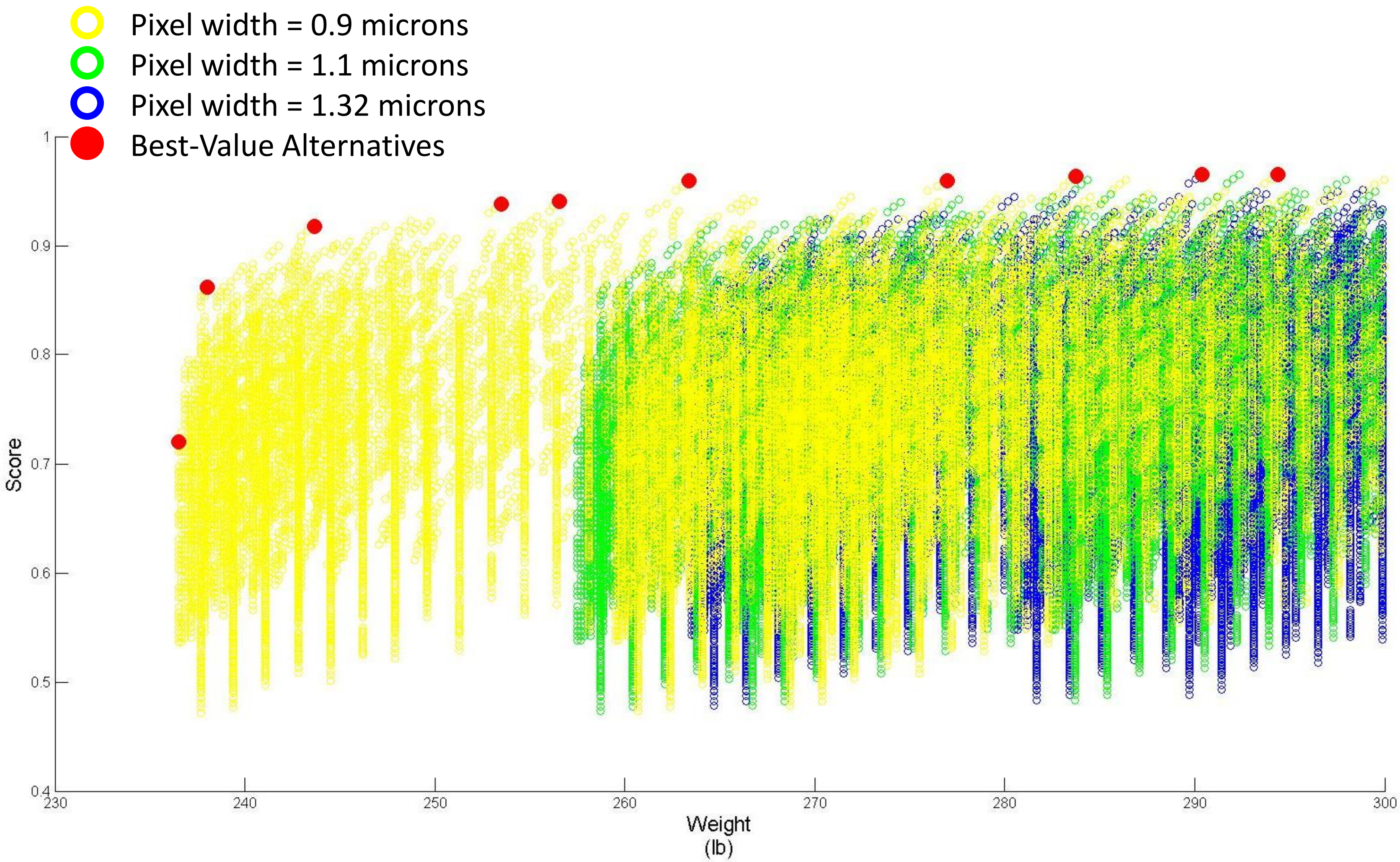
Results - HDDs vs. SSDs



Results - FoV


FoV = 6 km
FoV = 8 km
FoV = 10 km
Score
Weight
(lb)
1
0.9
0.8
0.7
0.6
0.5
0.4
230
240
250
260
270
280
290
300

Results – Sensor Types



Results - Gimbal