Six Challenges for Energy-Constrained Collaborative Sensors

(Light-Weight Wireless Sensor Networks)

Presented to

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Outline

- Energy-constrained collaborative processing defined
- Six challenges
- Summary

Energy-Constrained Collaborative Sensing – *What is It?*

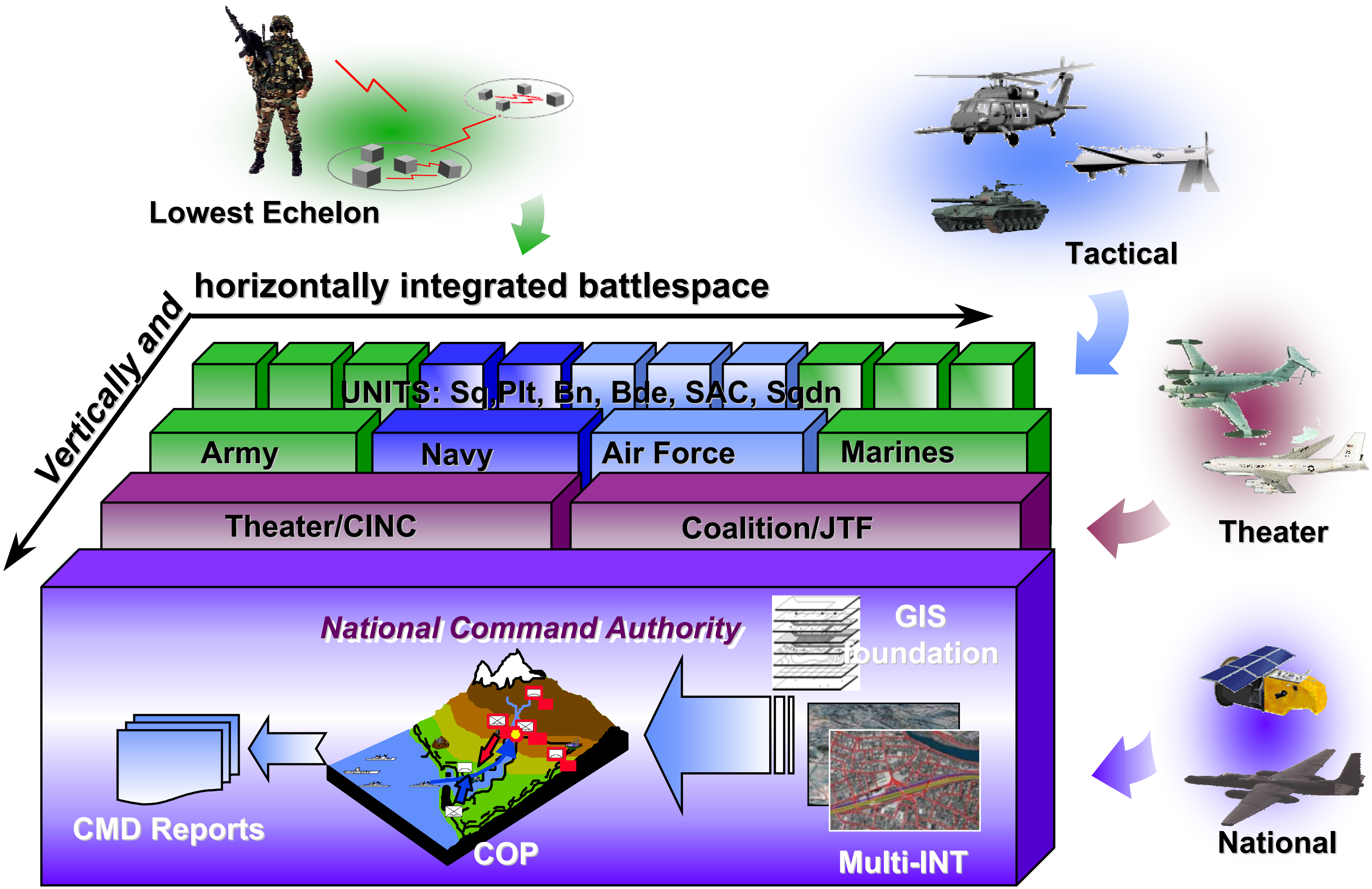
- **Individual nodes are small, low-cost, low-power thereby enabling**
  - Low-echelon deployment and tasking (ownership by the masses)
  - Variety of emplacement methods (hand, air-drop, artillery)
  - Affordable proliferation (military, homeowner, NASA)

- **Small size and low cost implies nodes have limited range, directionality, reliability**

- **Collaboration enables high aggregate performance**
  - Reliable detection
  - Tracking
  - Geolocation (fusing of bearings from multiple nodes)
  - Target recognition and classification

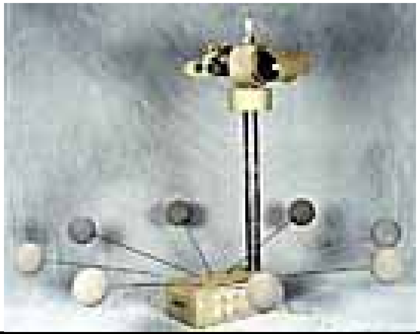
- **Robust wireless networking supports global reach**

Energy Constrained Collaborative Sensing in the Military Context



Challenge 1: Prove the Assertion that *"Smaller is Better"*

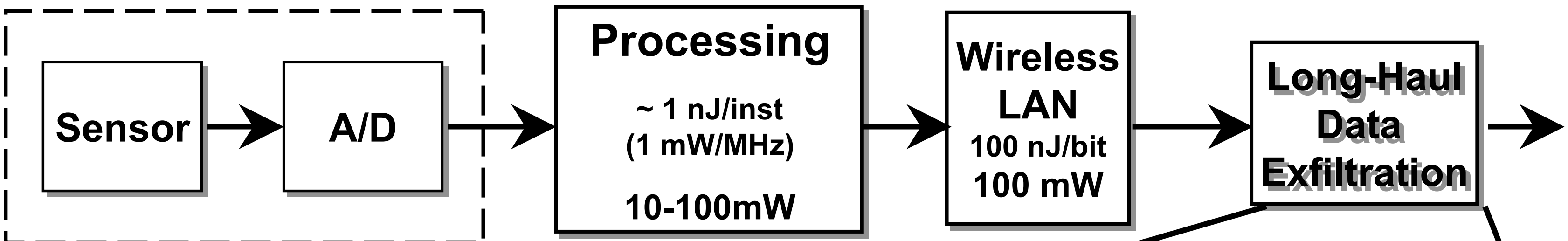
- **Historically, R&D investments have emphasized higher performance sensors (e.g., longer range, higher resolution, etc.)**
- **Military experience with unattended ground sensors mixed**



Parameter	*Remote Sentry*[1]	*IDEWS-MN*[2]	*WINS NG 1.0*[3]
Volume (cm^3)	**100,000**	**885**	**5015**
Projected unit cost ($K)	**$120**	**$1.5**	**< $0.5**
Acoustic sensor range(m)	**3000**	**350**	**50**
Communication			
– Frequency (MHz)	**138-153**	**138-153**	**2400**
– Tx power (mW)	**4000**	**2000**	**10**
– Range (m)	**< 8000**	**< 1500**	**< 50**
Networked	**No**	**No**	**Yes**
Other sensors	**FLIR/CCD/LRF**	**Seismic/mag/NIIR**	**Seismic/mag/NIIR**

[1]*Alliant Tech* [2]*L3 Communications* [3]*Sensoria*

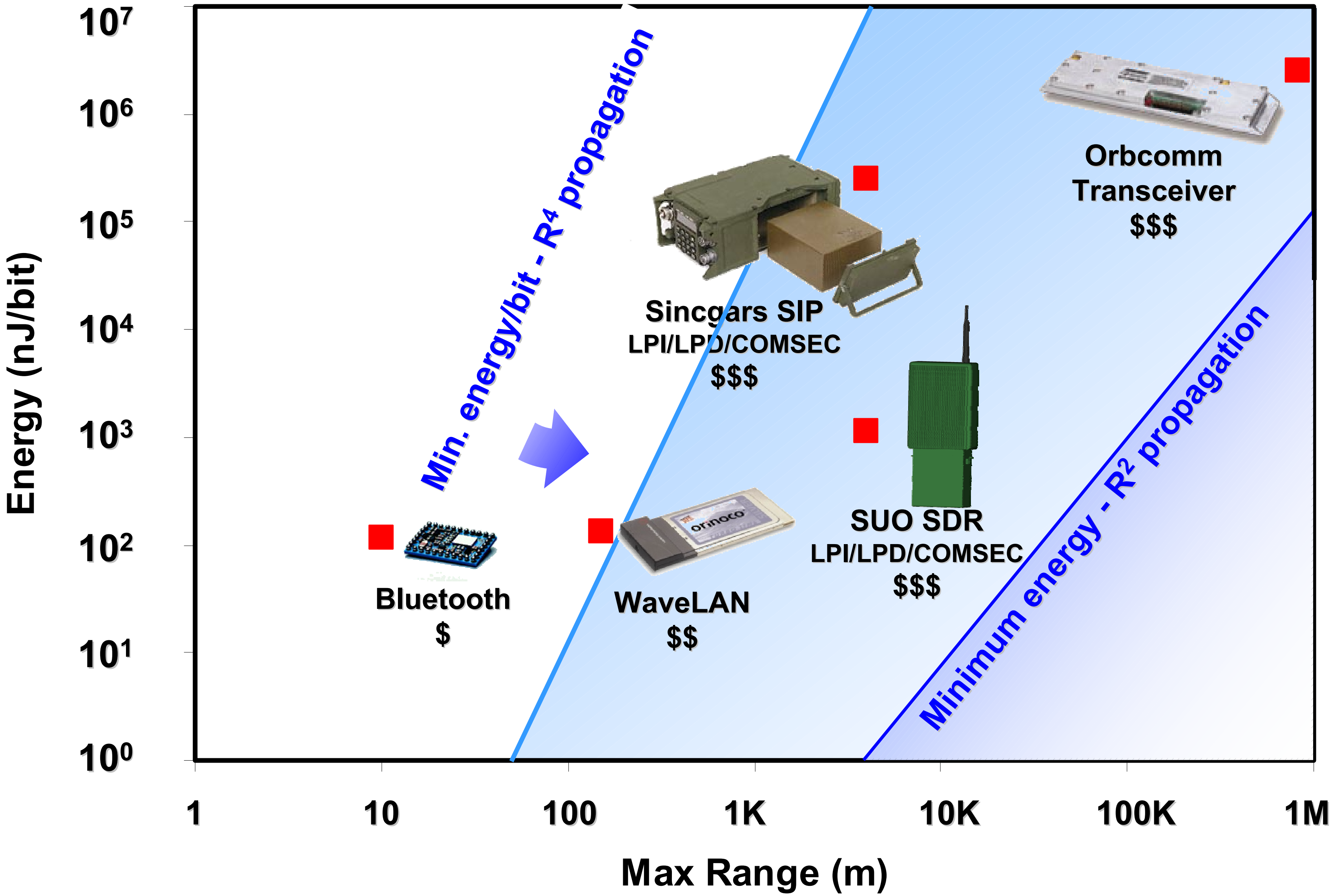
Challenge 2: Balance System Energy Use



Representative Node Types	*Sensor+A/D* Pwr (mW)	Rate (KHz)	nJ/ sample
Acoustic	.06	4	0.15
Seismic	.02	1	0.2
Visible Imager (APS)	30	12550	2.4
IR Imager (Indigo Ω)	1200	7300	164

Radio Type	Approx Range	Pwr (W)	Energy (nJ/bit)
WaveLAN (S)	150 m	1.4	125
Sincgars (VHF)	8 km	4	>350K
Freewave (L)	~80km	6	50K
Iridium (L)	>780 km	0.85	355K
Orbcom (VHF)	>800 km	6	2,500K

Challenge 3: Robust Low-Cost Wireless Links



Aspects of Link Robustness

- Reliability
- Availability
- Efficiency (bandwidth, energy)
- Covertness
- Security
  - Data
  - Network
- Scalability
- Reachability
- Cost effectiveness

Challenge 4: Distributed Query & Collaboration

- Query and Tasking Issues
  - Quality of Service
  - User authorization and conflict resolution
  - User and node authentication
  - Consolidation and re-hosting of queries and responses
  - Archival and retrieval of information in the network

- Collaboration
  - Heterogeneous sensors with different fields of regard
  - When is information sharing beneficial (cost in energy, bandwidth, loss of covertness versus benefits)?
  - How is heterogeneous information best combined?
  - Local autonomous collaboration for information aggregation and improved decision making

Challenge 5: Sensor Deployment

- Packaging
  - Environmentally hard (temperature extremes, moisture, corrosion)
  - Sensing robust in face of dust, snow, mud and other weather effects
  - Highly integrated to reduce size, weight, power, logistical cost
- Placement
  - Forward deployment (air drop, artillery launch)
  - Rapid deployment (volcano launch)
  - Optimum placement
    - » Mobility for optimizing sensor field of regard (rotational and translational)
    - » Geolocation selection to close local and long-haul links
- Resistance to countermeasures
  - Geolocation by RF means
  - Physical tampering, removal, theft or destruction
  - Spoofing and jamming
- Information security

Challenge 6: Develop Performance Benchmarks

- Benchmarks are well-defined problems that serve to focus and priotize R&D priorities and activities
- Characteristics of a good benchmark
  - Compelling application
  - Enable quantitative comparison of competing methods
  - Extrinsic and intrinsic performance metrics defined
    - » Example of extrinsic performance metric: P_d/P_{fa}
    - » Example of intrinsic metric: Network bandwidth used
  - Repeatable, supporting comparison of competing techniques
    - » Calibrated raw data
    - » Public
- To be effective, benchmarking must be supported at a level of at least 10-15% of total program value

Summary

- **Benefits of energy-constrained collaborative Sensing need to be clearly defined and quantified – *What are the killer apps?***

- **Technology innovations needed across the board (hardware, software, algorithms, architectures) to realize the vision**

- **Low-cost algorithms and architectures for distributed sensing, querying, deciding and acting are the enabling technology**

- **Rigorous, graduated benchmarks offer a means to focus and prioritize research, while demonstrating benefits in selected application areas**