Future Space System Support to U.S. Operations in an Ice-Free Arctic: Broadband Satellite Communications Options

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R&D Project

- 3-year project (2009-2011) funded by The Aerospace Corporation
- Research topics include:
  - *Current and future satellite coverage of Arctic region*
  - *Satellites for climate treaty monitoring*
  - *Space system support for climate change impacts*
- This presentation: Options for military broadband communications in an ice-free Arctic region

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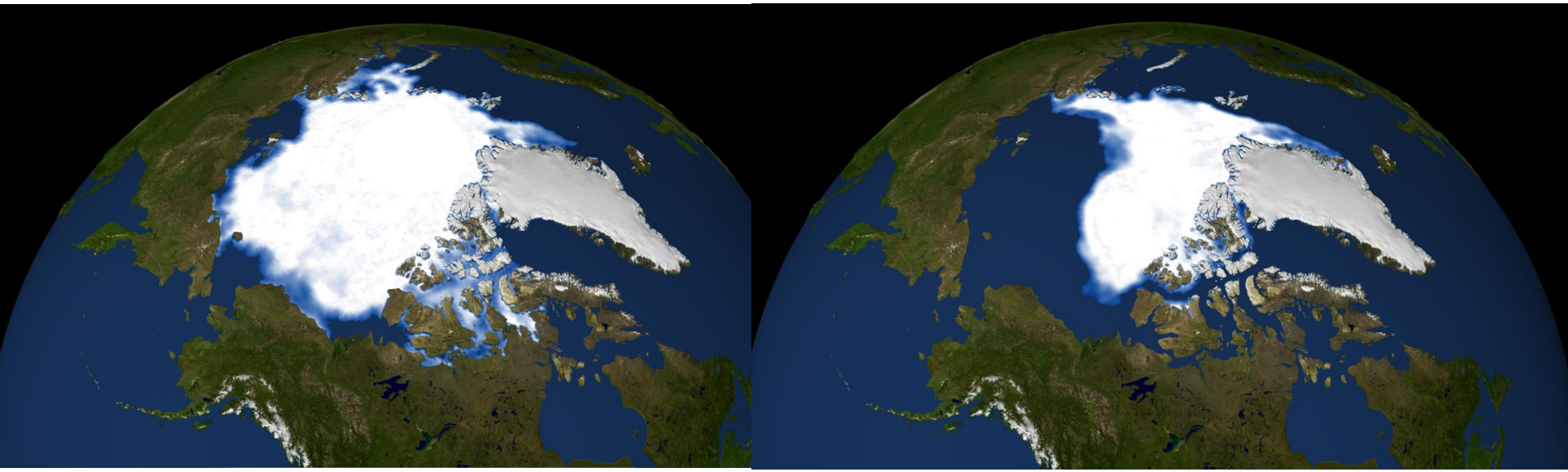
Arctic Ice Melt

September 1980 *September 2007*



Ice cap disappearing 3 times faster than predicted by IPCC models

--National Center for Atmospheric Research & UC Boulder joint study, May 2007

Photos reprinted courtesy of NASA GSFC

Polar Sea Routes Opening During Summers

*"…dedicated **polar space support concept of operations** is required…"*

- Navy conference on Arctic operations

Increasing DoD Interest in Arctic

- **An ice-free Arctic will open up a third continental coast line**
  - *U.S. and Canadian military activities in the region may soon increase*

- **National Security Presidential Directive** (Jan 2009)
  - *Secretary of Defense shall "…develop greater capabilities and capacity, as necessary, to protect United States air, land, and sea borders in the Arctic region…"*

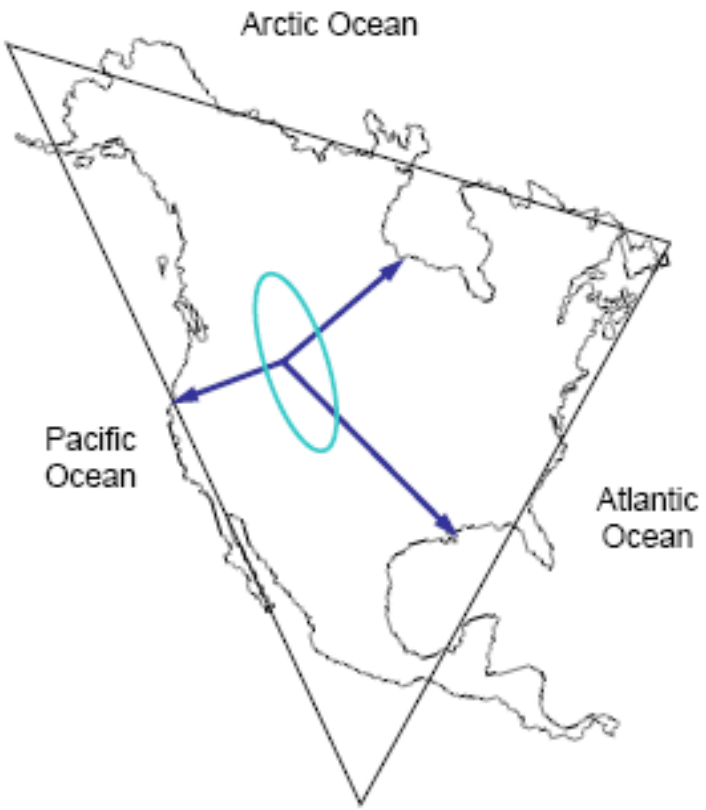


Image reprinted courtesy of Dr. Stewart Rood, University of Lethbridge

Activities in Arctic Increasing Rapidly

- 6,000+ ships currently operate in Arctic waters
  - *U.S. Coast Guard has only three ice breakers (Navy none)*
    - Both "heavy icebreakers" currently not operational:
      - *Polar Sea* back by early 2011?
      - *Polar Star* back by 2013?
    - One "medium icebreaker": *Healy*
  - *Rescue helicopters 8 hours away from cruise ships in trouble*
- Northeast Passage (near Russia) will have most commercial traffic
  - *Russia offers ice-breaker services and has string of coastal ports*
  - *Problems with unstable ice flows in island channels in Northwest passage*
- Ore and fossil fuel becoming more accessible. Examples:
  - *18 millions tons a year of iron ore to Europe from Baffin Island*
  - *Norilsk Nickel, largest nickel and palladium producer, has developed its own ice-reinforced shipping fleet*
  - *Accessible oil and gas reserves are near coasts, within national boundaries (once these are finalized)*
  - *Very serious environmental risks (oil spills especially, due to cold)*
  - *Alaska Arctic shore may soon be opened to access oil and gas*

National Security & Coast Guard Concerns in Arctic

- Border and territorial enforcement
- Sea and air traffic control
- Search and rescue — a sinking cruise ship with 500 passengers may be 8 hours away by helicopter
- Environmental disaster — a Gulf-like oil spill would be much more serious due to fragile habitat, lack of clean-up infrastructure and cold sea temperatures

Current Satellite Coverage of Arctic

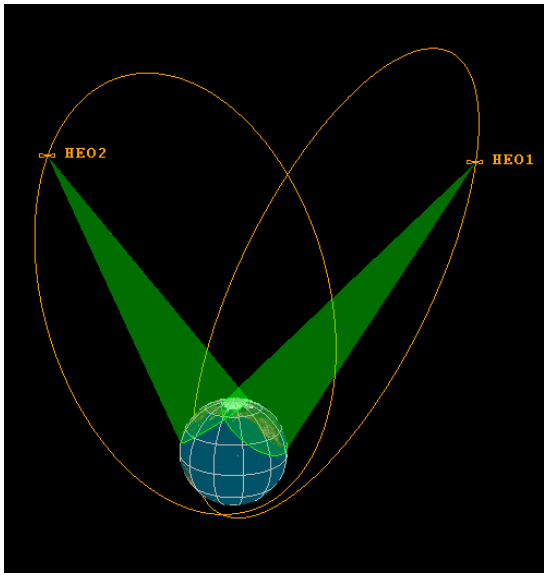
- Imaging and remote sensing satellites in sun synchronous LEO orbits
  - *Some sensors hampered by darkness and bad weather*
- GPS navigation coverage
  - *Slight accuracy degradation due to low elevation angles and increased ionosphere effects*
- No coverage by GEO communication satellites
  - *U.S. military communications via hosted payloads and Iridium*
  - *Leasing commercial GEO transponders not an option*

Future Need for Arctic Broadband Communications

- U.S. military support
  - *UAVs*
    - High resolution sensors generate 100s of Mbps
  - *Ground sensors, AWACS*
    - Large amounts of real time data
  - *Remote sensing & surveillance systems*
    - Data requires ground processing before distribution
  - *Navy/Coast Guard ship communications*

- Civil and commercial support
  - *Cruise ships and airlines*
  - *Search and rescue*
  - *Exploration platforms*
  - *Scientific*

Arctic Broadband Communication Options



- Russian Molniya communications satellites operational since 1960s
  - *Planned Arktika system (5 satellites; first launch 2010)*
- Iridium Next and Canadian PCW systems plan to offer 10 Mbps bandwidth services
- Tight budgets and limited military operations in the next decade make prospects for dedicated U.S. military Molniya broadband system very unlikely in near term
- CSA has proposed a dedicated Molniya system—perhaps a potential opportunity for joint development with US but funding appears unlikely
- Commercial satcom options?
  - *Purely commercial business case risky until demand better established*
  - *DoD partner in commercial development being explored*

Arctic Coverage as a Function of Orbit Type

	Orbit Type	3 Polar GEO	2 Polar GEO	4 Incl GEO (35°)	3 Incl GEO (35°)	3 Tundra GEO	2 Molniya HEO	4 Magic MEO	3 Magic MEO	20 SS LEO	16 SS LEO	5 SS LEO	3 SS LEO
	# Orbit Planes	1	1	4	3	3	2	4 (2)	3	2	2	5	3
	Orbit Period (hr)	24	24	24	24	24	12	3	3	1.7	1.7	1.7	1.7
Elev > 20 deg | Elev > 10 deg	Time in View (%)	100	75	>95	<75	100	100	100 (99)	95	90	75	>25	<25
	Avg Revisit Time (min)	0	180	<60	>360	0	0	0 (1)	5	10	15	20	60
	Max Revisit Time (min)	0	>210	<60	>360	0	0	0 (1)	7	20	25	70	60
	Time in View (%)	99	60	>50	<50	~100	100	99 (85)	75	50	50	<25	<25
	Avg Revisit Time (min)	15	>210	360	>720	~0	0	5 (15)	25	15	20	30	60
	Max Revisit Time (min)	30	>210	360	>720	~0	0	10 (20)	35	30	30	80	120

Figure courtesy of Thomas Lang, The Aerospace Corporation, 2009.

ROM Estimates for 2 ComSats in Molniya Orbits

Launch Vehicle Class	LEO Perf [&] (WR) kg	Molniya Perf [&] kg	S/C Wet Mass	S/C Mass in Molniya kg	Payload Mass kg	Comm Capacity per S/C	LV cost * $M	# LV	SC Cost * $M	# SC	Total Cost [&&] $M	Notes
EELV Med, M+ Class		3000 kg +	3500 kg	3500 kg	1000 kg	~1 Gbps	$150M	2	$350M	2	$1B	
EELV Med, M+ Class	7000 kg +		3500 kg	1500 kg	400 kg	~300 Mbps	$150M	1	$200M	2	$550M	Dual Launch [#]
Delta II/Taurus II Class	3500 kg		3500 kg	1500 kg	400 kg	~300 Mbps	$80M	2	$200M	2	$560M	
Delta II/Taurus II Class	3500 kg		1900 kg	700 kg	150 kg	~100 Mbps	$80M	1	$100M	2	$320M	Dual Launch [#]

* costs are ROM, for relative comparison only

** Transfer from inclined LEO to Molniya using on-board propulsion

*** Combined data rate of Ka and X band channels

[&] Performance numbers are approximate, for the class of vehicles

[&&] Does not include ground terminal or network costs

[#] Dual launch capability not available for EELV yet

Assessment of Polar Broadband Comm Options

Assessment Criteria	Hosted	Dedicated	Combined	Shared	Leased
Costs (space segment, user segment, operations)	Y	R	R	Y	G
Levels of satisfaction of various users' needs	R	G	G	Y	Y
User segment requirements & contraints	R	G	G	Y	Y
Auxiliary mission capacity (e.g., secondary payloads)	R	Y	Y	Y	R
Schedule (time required to develop & deploy)	Y	R	R	R	?
Interoperability (e.g., connection to GIG)	Y	G	G	Y	R
Flexibility (e.g., adaptable to changes in need or technology)	R	Y	R	Y	R
Sustainability (e.g., replenishment constraints)	R	G	G	Y	Y
Availability (e.g., hosted payloads are secondary)	R	G	G	G	R
Security (e.g., jamming, tamper resistance)	Y	G	G	Y	R
International participation (e.g., cost sharing)	R	Y	Y	G	G
Leveraging commercial systems (e.g., Iridium)	R	R	R	R	G
Risks (e.g., technical, cost, schedule)	Y	Y	R	Y	?

(G=excellent; Y=moderate; R=poor)

Overall Assessment of Broadband Satellite Capabilities and Costs

- Preliminary study by The Aerospace Corporation
- Observations
  - *Cost versus performance for various launch options to Molniya orbits*
  - *Federal procurement would take about 8 to 10 years, starting now*
  - *Current and projected space budgets severely constrained*
  - *Arctic melting time line uncertain, no strong sense of urgency—yet*

- **Conclusion:**

  New dedicated DoD Arctic communications satellite program highly unlikely due to uncertainty in Arctic melting and other space budget priorities

Business Case for Hosted DoD Broadband Payload

- Higher costs work against purely commercial business case
  - *Two satellites in Molniya orbits are required to provide continuous coverage versus a single geostationary satellite at lower latitudes*
  - *Satellites require radiation hardening or will have shorter lifetimes*
  - *Demand and spot lease revenue will be highly seasonal*
  - *Investors will seek higher expected returns to compensate for risks, which include demand uncertainty, unresolved treaty issues, and non-GEO satellite development and operations*
- Our assessment:
  - *Arctic will remain a relatively small commercial broadband market for many years*
  - *US (and perhaps international) partnership might close business case earlier than otherwise*

Potential DoD Opportunities for Cooperation

- PCW (Canadian Polar Communications and Weather System)
  - *What would be the cost to participate?*
  - *How much bandwidth would be available to the US military?*
- Iridium Next
  - *US military currently largest user of Iridium*
  - *How much bandwidth would be available (10 Mbps?)*
  - *Is Iridium Next development financing still an issue*
- A potential new commercial broadband system?
  - *ESA study looking into business case*
  - *If commercial development proposed, should the DoD participate?*

Summary

- Arctic melting faster than predicted
- US military and Coast Guard activities in Arctic may start increasing as early as 2013
- Space support essential due to lack of Arctic infrastructure
  - *Europe, Russia and Canada ahead of US in planning*
- Arctic broadband communications needed—there could be a gap
  - *Military UAVs likely to play big role in Arctic*
  - *Potential opportunity: US participation in joint or commercial development*
- Other military space requirements for Arctic region will arise
  - *Detailed ice and maritime traffic surveillance, for example*

References

1. Shipley, D., “Arctic Sea Ice Extent Trending Below Record 2007 Melt,” *The Daily Green*, June 12, 2009. Accessed on July 13, 2009, at
2. http://www.thedailygreen.com/environmental-news/latest/arctic-sea-ice-47061201.
3. Amos, J., “Arctic summers ice-free ‘by 2013’,” *BBC News*, December 12, 2007. Accessed on July 13, 2009, at http://news.bbc.co.uk/2/hi/science/nature/7139797.stm.
4. “Global Warming Speeds Up Race for North Pole,” *Jane’s Defense Weekly*, January 16, 2008.
5. Borgerson, S., “Arctic Meltdown: The Economic and Security Implications of Global Warming,” *Foreign Affairs*, March/April 2008.
6. Goldberg, M., “About that Russian Arctic ‘Claim’,” *UN Dispatch: Posts on the UN,* August 20, 2007. Accessed on July 24, 2009 at http://www.undispatch.com/archives/2007/08/about_that_russ.php.
7. Smith, P., Wickman, L. and Min, I., "Future Space System Support to U.S. Military Operations in an Ice-Free Arctic: Broadband Satellite Communications Considerations," paper presented at AIAA Space 2009 conference, Pasadena, CA, September 14, 2009.
8. Figure courtesy of NASA Goddard Space Flight Center, accessed on July 23, 2009, at http://gsfc.nasa.gov.
9. *National Security and the Threat of Climate Change*, Military Advisory Board Report, The CNA Corporation, Alexandria, VA, 2007.
10. *National Security Presidential Directive 66/Homeland Security Presidential Directive 25*, accessed on July 13, 2009, at http://blog.usni.org/?p=833.
11. *The Foreign Policy and National Security Implications of Global Climate Change*, CSIS Report, November 2007.
12. *National Security and the Threat of Climate Change*, CNA Corporation Report, 2007.
13. *Climate Change and National Security*, Council on Foreign Relations, November 2007.
14. “Arctic Security,” Editorial, Canadian Naval Review, Vol 1, No. 4, Winter 2006.
15. Purvis, N. and Busby, J.W., “The Security Implications of Climate Change for the UN System,” United Nations High-Level Panel on Threats, Challenges, and Change, Washington, DC, 2004.
16. Impacts of a Warming Arctic, Cambridge University Press, 2004.
17. “Project Polar Epsilon Will Enhance Canada’s Surveillance and Security Capability,” DND/CF News Release, 2 June 2005. Accessed on July 23, 2009 at http://www.forces.gc.ca/site/newsroom/view_news_e.asp?id=1674 ;
18. Thorne, S., “Feds Look to Satellite to Assert Arctic Sovereignty,” *Canadian Press*, 28 August 2005.
19. Huebert, R., “A Maritime Security Perspective,” paper presented at conference hosted by the Centre for Foreign Policy Studies, The Centre for Military and Strategic Studies, University of Calgary, 10-12 June 2005. Accessed on July 23, 2009, at http://www.cfps.dal.ca.
20. “The Arctic Ocean and Climate Change: A Scenario for the U.S. Navy,” Arctic Research Commission, 2000.
21. Chalecki, E., "He Who Would Rule: Climate Change in the Arctic and its Implications for U.S. National Security," paper presented at the annual meeting of the International Studies Association 48th Annual Convention, Chicago, IL, February 28, 2007.
22. Borgerson, S., “Arctic Meltdown: The Economic and Security Implications of Global Warming,” *Foreign Affairs*, March/April 2008.
23. “Is America Prepared For An Accessible Arctic?” Testimony by Mead Treadwell, Chair, U.S. Arctic Research Commission, Senate Commerce Committee Hearing; *Climate Change Impacts on The Transportation Sector,* Washington, D.C., June 24, 2008.
24. *SSC San Diego Command History Calendar Year 2005,* Technical Document 3200, United States Navy, Space and Naval Warfare Systems Center San Diego, San Diego, CA, March 2005.
25. Admiral Thad Allen, USN, in Luncheon Address at the 37th Institute for Foreign Policy Analysis-Fletcher School Conference on *A New Maritime Strategy for Twenty-First Century National Security*, Washington, D.C., September 27, 2007.
26. *Naval Operations in an Ice-free Arctic, Symposium Report,* Office of Naval Research, 17-18 April 2001; “Impact Of An Ice-Diminishing Arctic on Naval and Maritime Operations,” July, 2007. Accessed on July 24, 2009, at http://www.orbit.nesdis.noaa.gov/star/IceSymposium.php.
27. *First Workshop on Satellite Imaging of the Arctic*, Niels Bohr Institute, University of Copenhagen, Copenhagen, Denmark, August 20-21, 2008.
28. *Report to Congress: U.S. Coast Guard Polar Operations,* directed by the Committees on Appropriations of the 110th Congress, 2008. Accessed on July 24, 2009, at http://www.uscg.mil.
29. Fetterer, F., and Fowler, C., *National Ice Center Arctic Sea Ice Charts and Climatologies in Gridded Format,* National Snow and Ice Data Center, Boulder, CO, January 1, 2006. Accessed on July 24, 2009, at http://nsidc.org/data/g02172.html. “Radarsat-2: A New Era In SAR,” accessed on July 24, 2009, at http://www.radarsat2.info/about/mission.asp.
30. Colussy, D., “Communications in the Great North: Alaska, The Arctic and Global Communications,” Iridium website, August 29, 2006. Accessed on July 23, 2009, at http://www.iridium.com.
31. *National Security Space Acquisition Policy,* Number 03-01, SAF/USA, U.S. Department of Defense, 27 December 2004.
32. Caceres, M., “Industry Insights - LEO Mobiles: The Next Generation,” *Aerospace America,* June 2007.
33. Iridium website, accessed on July 23, 2009, at http://iridium.mediaroom.com/.
34. Garand, L., and Kroupnik, G., “Status of the Polar Communications and Weather (PCW) mission to serve the Arctic,” *First Workshop on Satellite Imaging of the Arctic*, Niels Bohr Institute, University of Copenhagen, Copenhagen, Denmark, August 20-21, 2008.
35. “Russia to Launch Space Project to Monitor the Arctic in 2010,” *SpaceMart,* January 30, 2008. Accessed on July 24, 2009, at http://www.spacemart.com/reports/Russia_To_Launch_Space_Project_To_Monitor_The_Arctic_In_2010_999.html.
36. Russian Satellite Communication Company website, accessed on July 24, 2009, at *www.rscc.ru/en/company/publ/2008.04.29.html*.
37. European Space Agency website, accessed on July 24, 2009, at http://www.esa.int/esaCP/index.html.