

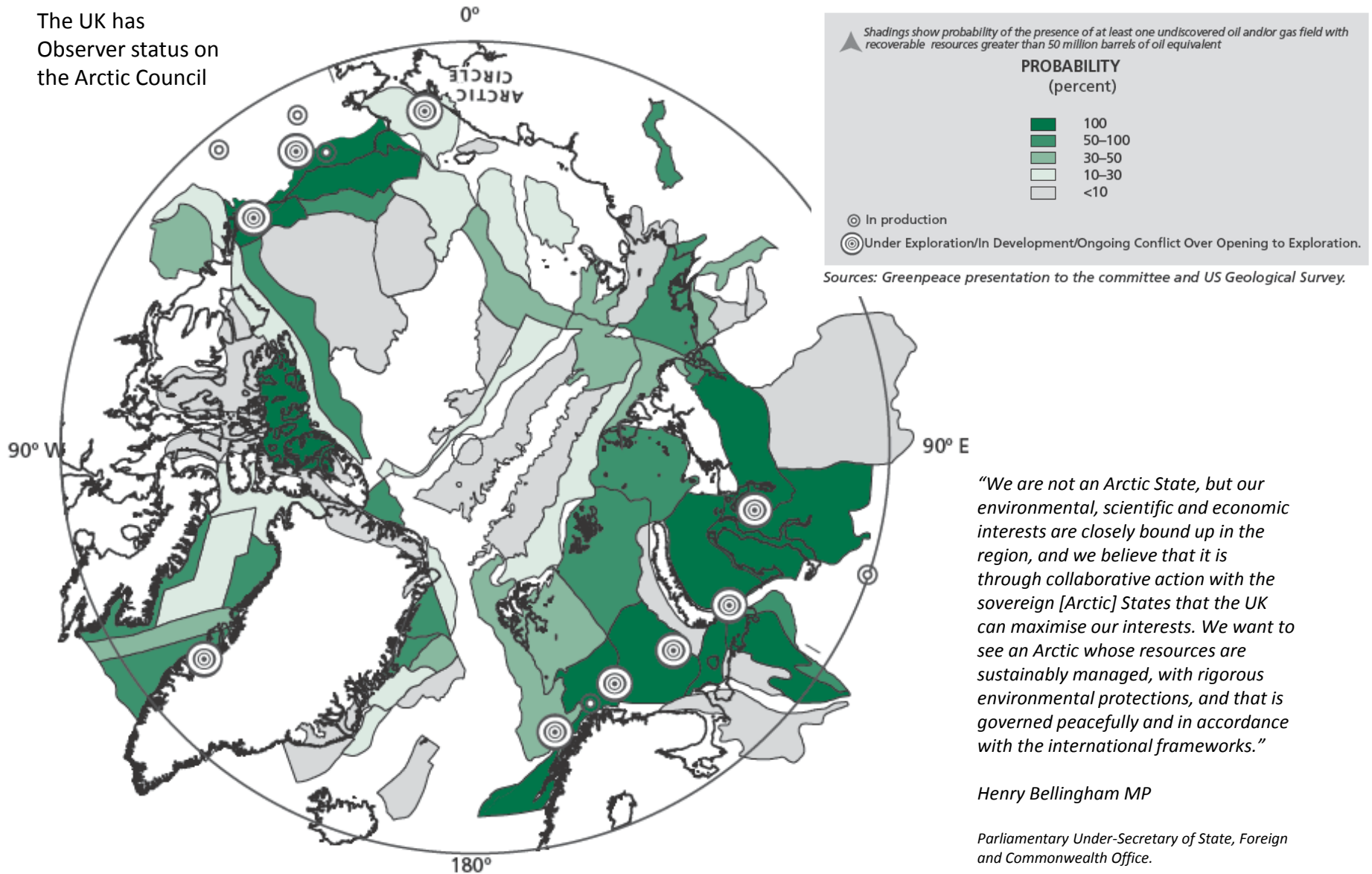
# Space missions serving the Arctic

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# Potential Arctic Oil/Gas Reserves

The UK has  
Observer status on  
the Arctic Council

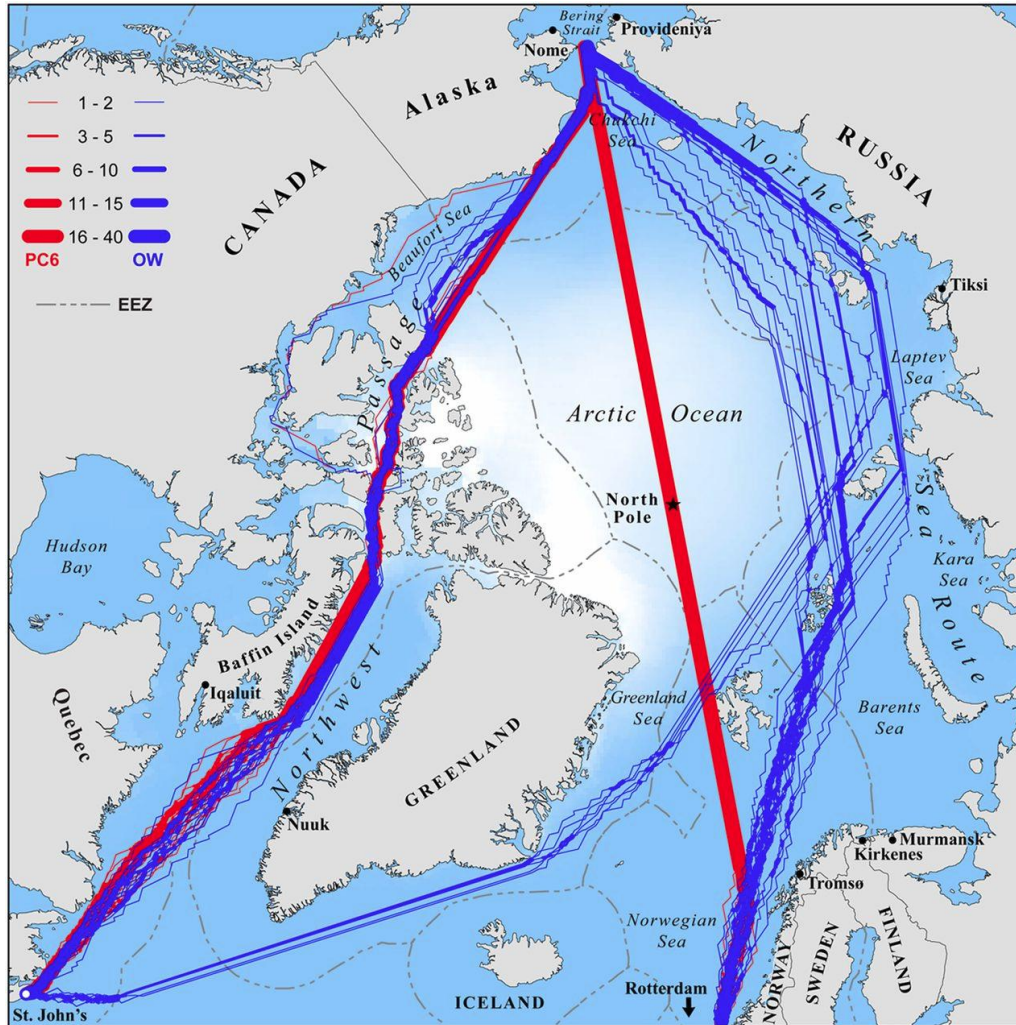


*“We are not an Arctic State, but our environmental, scientific and economic interests are closely bound up in the region, and we believe that it is through collaborative action with the sovereign [Arctic] States that the UK can maximise our interests. We want to see an Arctic whose resources are sustainably managed, with rigorous environmental protections, and that is governed peacefully and in accordance with the international frameworks.”*

*Henry Bellingham MP*

*Parliamentary Under-Secretary of State, Foreign and Commonwealth Office.*

# Expected new shipping routes (~2050)



*Optimal September navigation routes for hypothetical ships seeking to cross the Arctic Ocean between the North Atlantic (Rotterdam, The Netherlands and St. John's, Newfoundland) and Pacific (Bering Strait) during the consecutive years of 2040–2059 as driven by ensemble-averaged general circulation models' projections of sea ice concentration and thickness assuming a **medium-low** (+4.5 W/m<sup>2</sup>) increase in climate forcing.*

# Conventional space infrastructure

- **GEO missions**
  - Cannot image high latitudes much above  $\sim 60^\circ$ .
  - Low resolution imagery, but good temporal sampling.
  - Satcomm access falls off rapidly as latitude increases, and GEO satellites are below the horizon above  $\sim 80^\circ$  (cf Svalbard) and tends to require large dish antennas.
  - NB Fibre now connects Norway to Svalbard – other long-distance subsea fibre projects are in planning
- **Navigation**
  - GNSS spacecraft in MEO at relatively low inclination, plus ionospheric disturbances above  $70^\circ$ .
  - Galileo is a little better than GPS at high latitudes
- **LEO missions**
  - Many EO spacecraft in  $82^\circ$  inclination or lower, 800km orbit, poor access to highest latitudes
  - High resolution, but poor revisit times (high revisit needed to mitigate clouds)
  - Iridium comms ( $86.4^\circ$  inclination, 741km)
    - *Low data rates currently but next generation constellation will have Ka-band services up to 8Mbit/s*
- **Molniya-like orbits**
  - Russia uses (since the 1960s) HEO orbits ( $63.4^\circ$ ) to provide comms and TV to northerly communities

# Space Solutions(1)

## CASSIOPE Mission - Canada

- Elliptical Polar Orbit
- Space weather ionosphere (ePOP) – an 8 instrument science package
- Broadband data comms – (Cascade) – file store and forward
- Up to 1.2Gb/s T&R, store up to 500GByte.
- Status
  - Smallsat mission for University of Calgary
  - PPP initiative
  - Launch July 2013 – awaited



## Polar Comms & Weather mission (PCW) – Canada

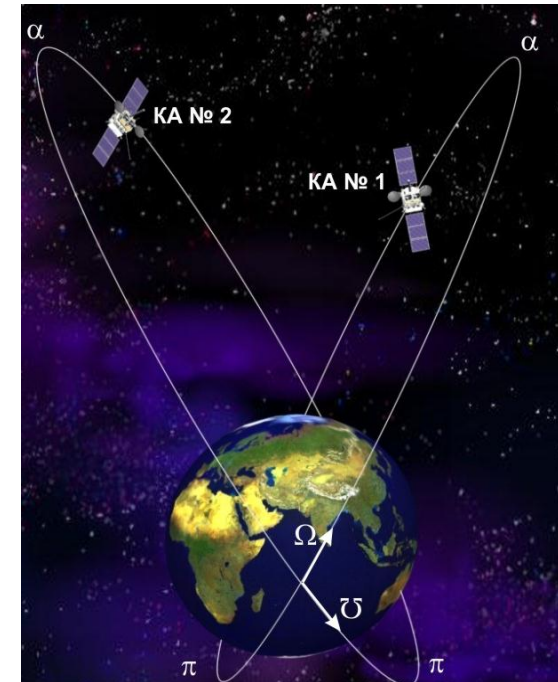
- Twin Highly Elliptical Three Apogee (TAP) Orbits (HEO - TAP)
- Surface and atmosphere EO
- Data comms (capacity TBD), meteo & space weather instruments
- Status:
  - Phase A complete
  - Awaiting funding and possible international partners
  - Looking for PPP procurement summer 2013
  - Services due to start 2018



# Space Solutions(2)

## Arktika – Russia

- HEO – similar to PCW
- Surface and atmosphere EO
- Space Weather
- Search and Rescue
- Broadband data comms – store and forward
- Status
  - Launch delayed from 2010 due to budgetary constraints
  - Expected 2015 and 2016



# Example Mission

## What is driving Canada's need for a mission?

- Needs are laid out in the URD for the Polar Comms and Weather (PCW) mission;
- This mission is awaiting approval beyond phase A, but is likely to go ahead eventually with international partners;
- Russia has a similar mission (Arktika) which may fly first...

# PCW

## Two satellites operating in complementary orbits to give:

- GEO-like imagery above  $50^{\circ}\text{N}$  every 15 minutes
- 24/7 high-rate data comms in Ka- and X-band
- Continuous space weather data
- Operational part of orbit is around apogee of  $\sim 40,000\text{km}$  so 'geostationary-like'
- Imaging conditions vary with distance, and Earth rotates under orbit plane so 'non geostationary-like'



# Canada's Needs (1)

## **Provide reliable 24/7 high data rate (HDR) communications services in order to:**

- enable Canadian Forces, Coast Guard, Fisheries and Oceans Canada, Nav Canada, Transport Canada, Indian and Northern Affairs Canada, Natural Resources Canada (NRCan) and Environment Canada activities in the high Arctic;
- enhance the connectivity of northern communities to the broadband information backbone infrastructure;
- facilitate exploration and exploitation of natural resources;
- enhance efficiency of the research in the Arctic
- ensure that Canadians are benefiting from increased air and marine traffic in the Polar region.

# Canada's Needs (2)

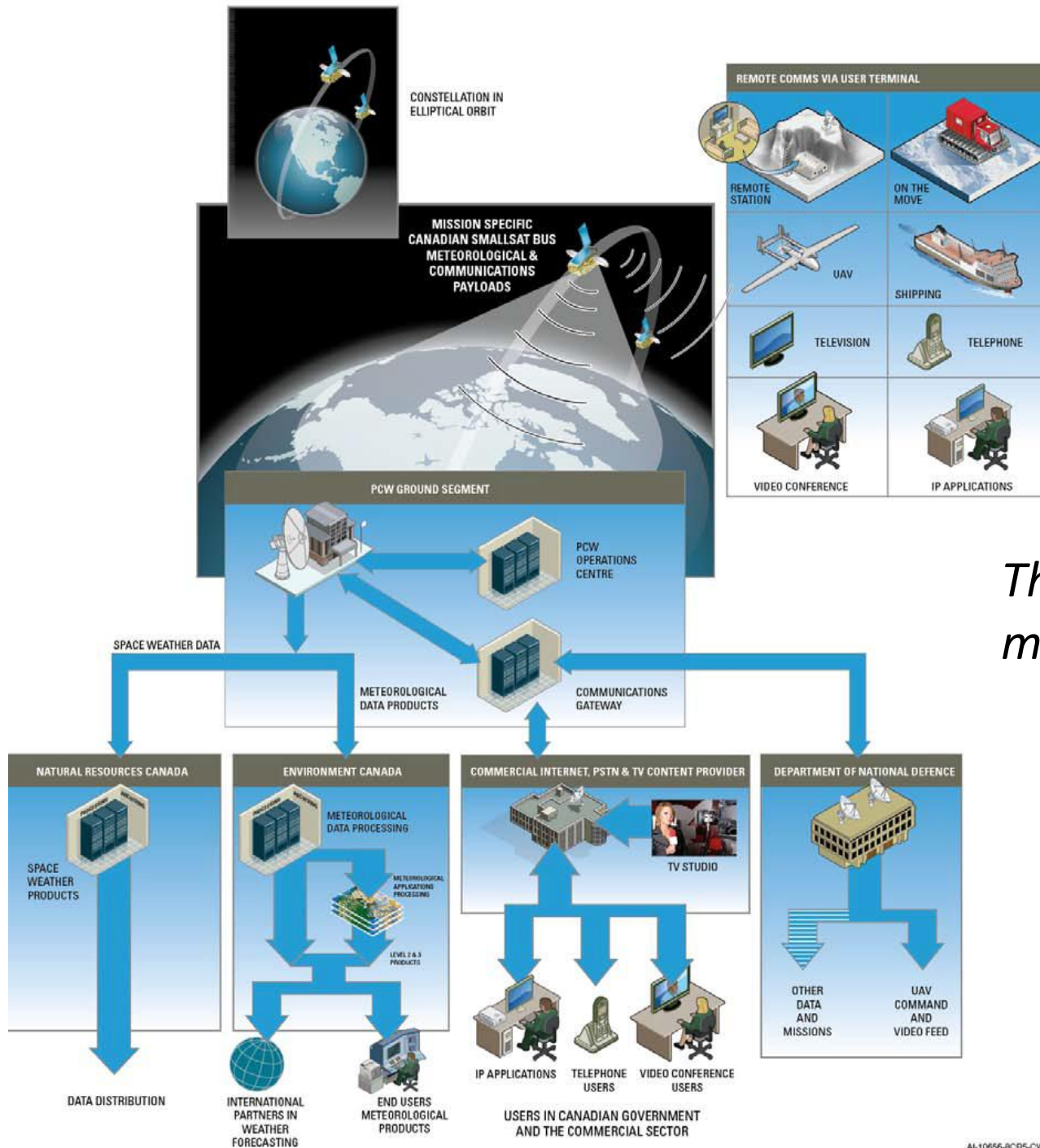
## Monitor Arctic weather and climate change for the benefits of Canadians and the Global community in order to:

- significantly improve the accuracy of weather forecasting, including severe weather event warnings;
- improve the understanding of global climate change and the ability to model and predict phenomena associated with it;
- provide unique high-quality operational data acquired over the entire polar region, which is currently not available from any source.

# Canada's Needs (3)

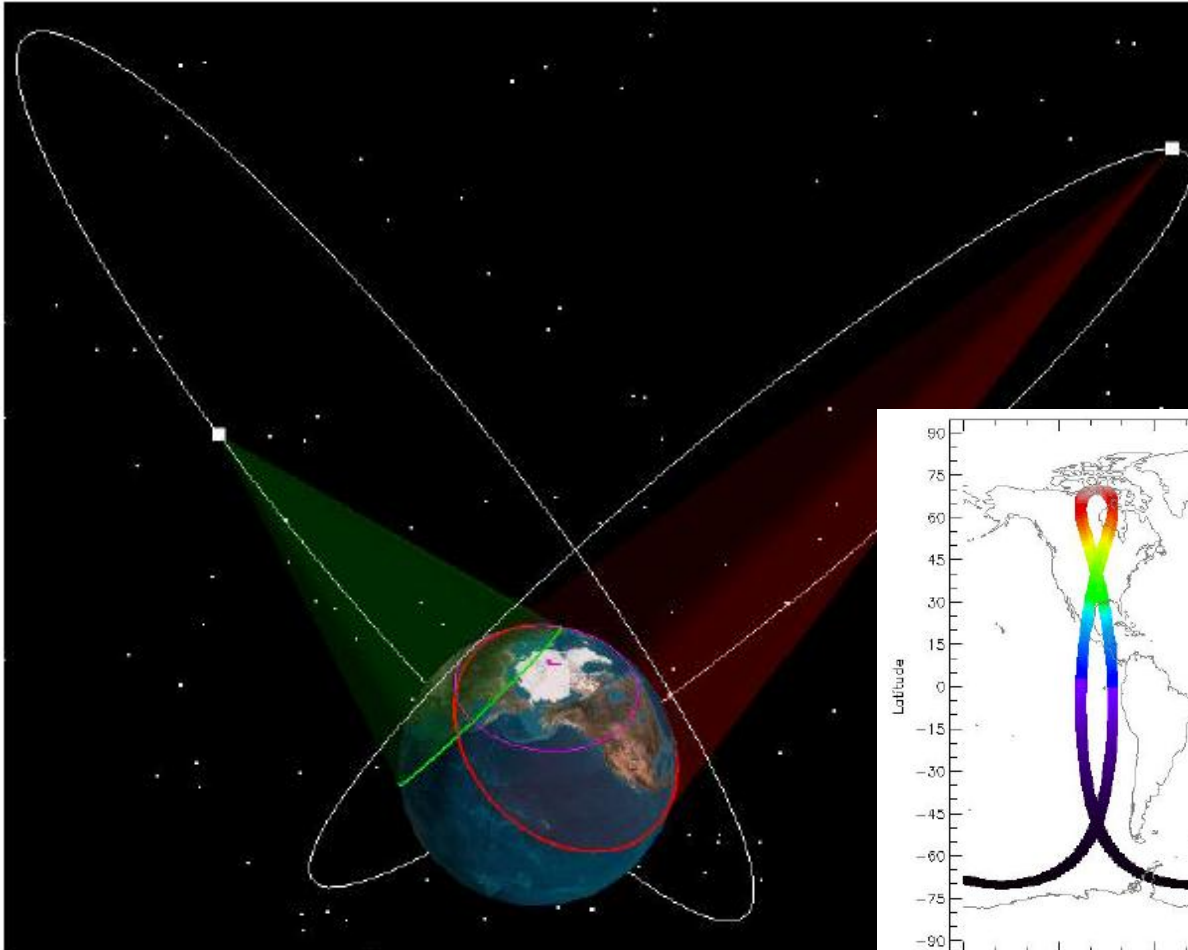
## Monitor space weather in HEO environment in order to:

- support the development of an alerting system for Polar Cap Absorption (PCA) events which strongly affect High Frequency (HF) communication in the Arctic;
- enhance the services of NRCan's Canadian Space Weather Forecast Centre (CSPWFC) to include HEO environment, and enable NRCan to develop a new service called “Space Anomaly Investigation System” which will identify Space Weather phenomena that contribute to satellite operation anomalies in HEO;
- support satellite developers and operators by improving existing models of Space Weather environment in HEO;
- support national and international Solar and Earth System scientific research in general.

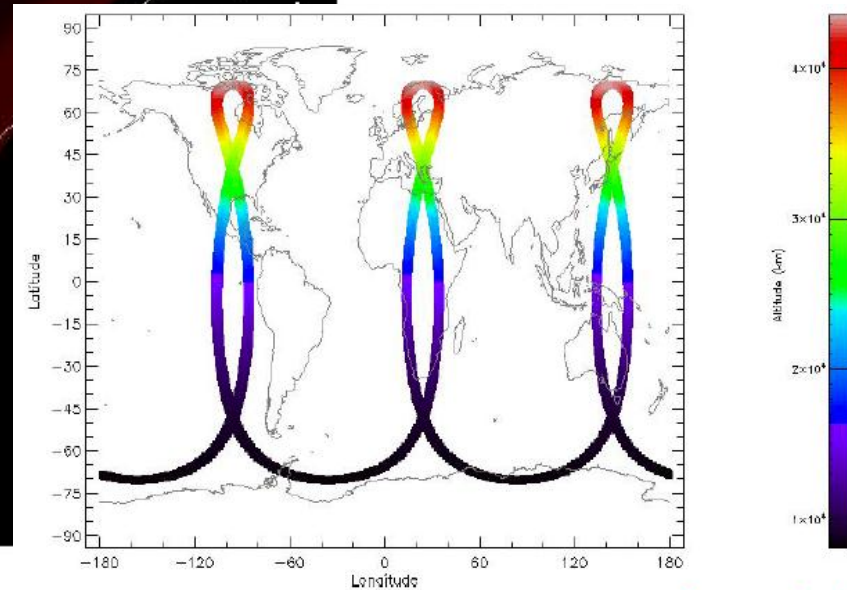


*The PCW overall mission concept*

# PCW Orbit



*16-hour HEO - TAP  
 gives good balance  
 between imaging  
 quality & spacecraft  
 longevity*



Three **AP**ogee (**TAP**) orbit

**Suggested apogees:  
 95°W; 25°E, 145°E**

# Issues with HEO orbits

- Stable  $\sim 62^\circ$  inclination still not ideal for Arctic viewing
- Variable ground motion
- Variable ground resolution – Earth image changes size
- Exposure to radiation – but mitigated by TAP orbit
- See Malcolm Macdonald's presentation for some novel options

# Summary

- Comms, EO and Space weather monitoring are likely to improve in the coming decade;
- Navigation?
- What services are needed?
- What (can the UK)/(does the UK want to) do?
  - Missions: bilateral/commercial?
  - Space instrumentation (CEOI/NSTP/ARTES/commercial)?
  - Downstream services (NSAP/IAP/commercial)?