Atmospheric Sciences Department, Org. 6913
Operations Safety, ES&H Overview, Engineered Safety Process

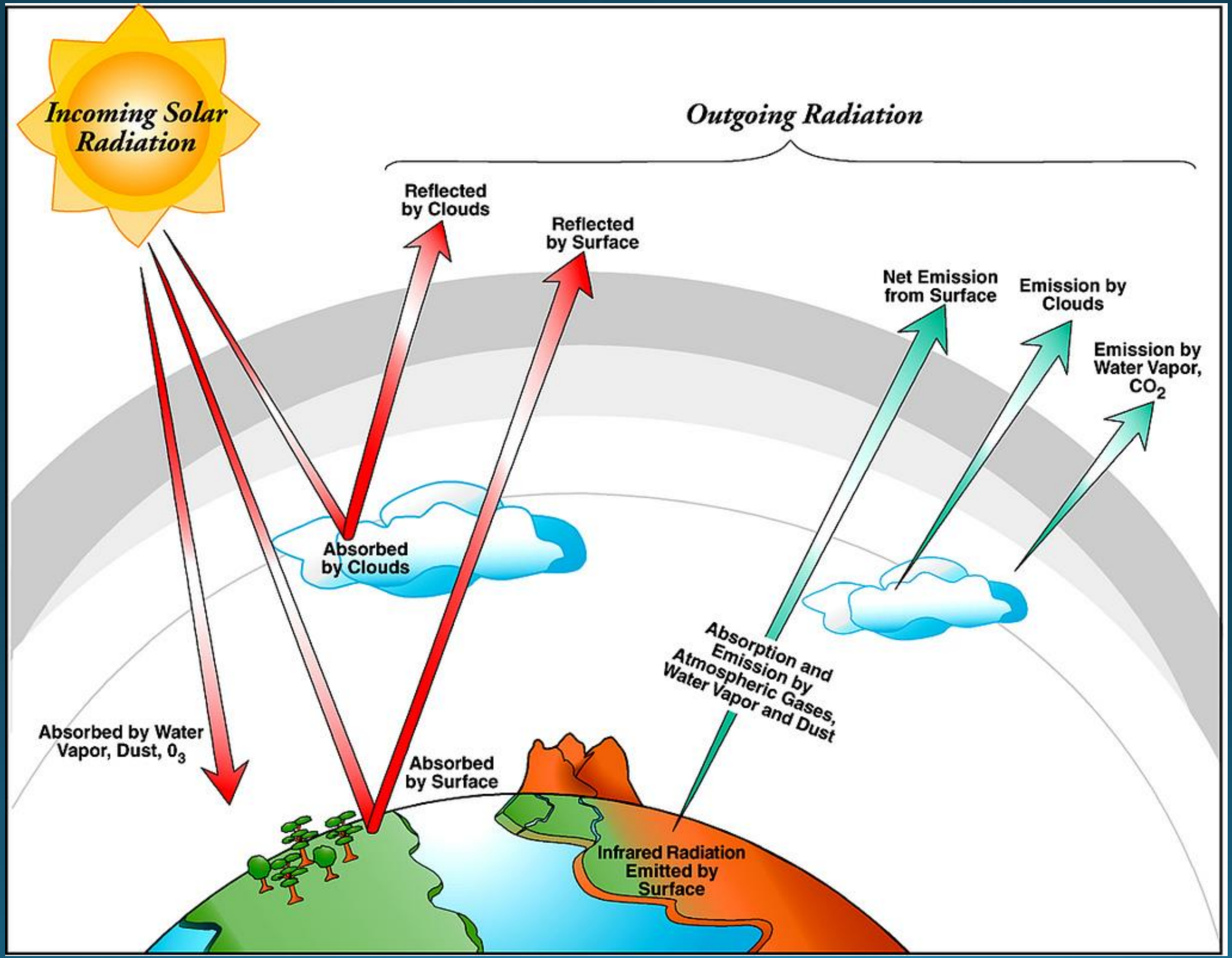
SAND2017-2463PE

- Why a team from Sandia is working in the Arctic -- Science drivers: earth system energy balance, clouds, earth system models
- What we do and where we work, the DOE Atmospheric Radiation Measurements (ARM) Program
- Vision for the Future – Sandia in the changing Arctic
- Engineered Safety: Our Experience to Date and Progress in the Journey
- Case in Point: The Oliktok Balloon Escape
- Current Opportunities for Improvement in ES&H and Challenges

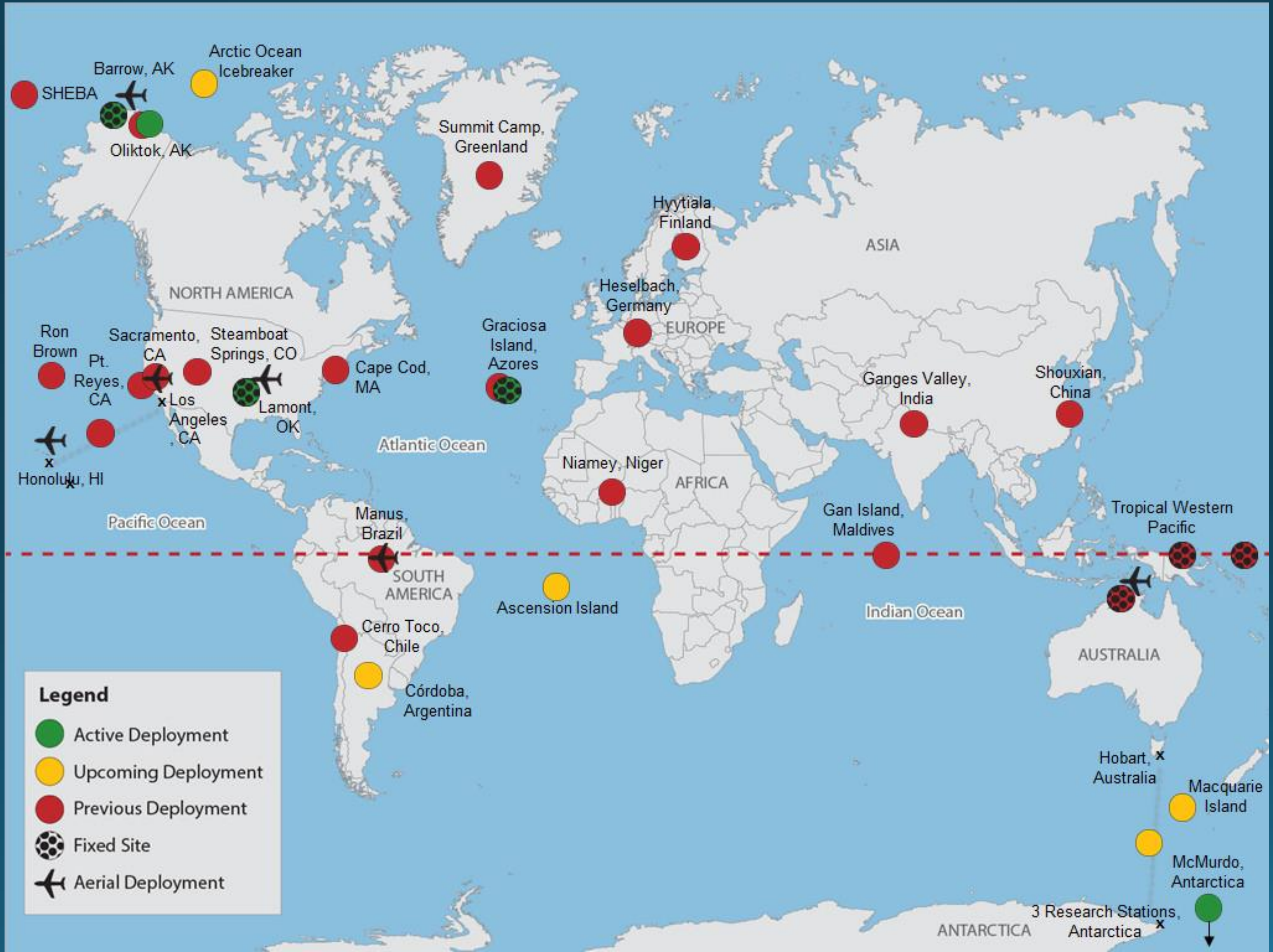
ARM North Slope Operations

- The ARM Mission is to provide the atmospheric research community with observations needed to improve understanding and representation in climate models of clouds and aerosols, including their interactions, radiative impacts, and coupling with the Earth's surface (graphic on next slide)
- DOE Sponsorship for Baseline Atmospheric Measurements
- ARM is based on a DOE Office of Science user facility model
- Principal Investigator-proposed, DOE-funded field campaigns and measurements
- Long term and short term "Intensive Operating Periods"
- Cooperation with Collaborating agencies, universities, private sector

Earth's Energy Balance: The Science Challenge

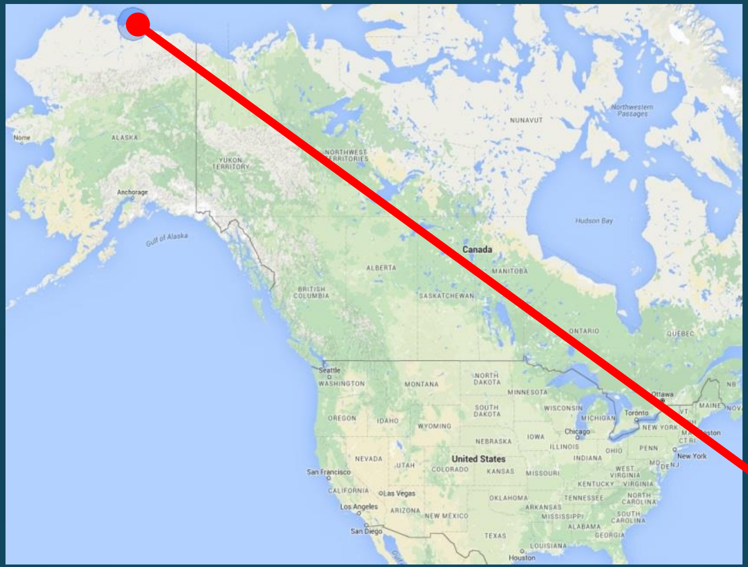


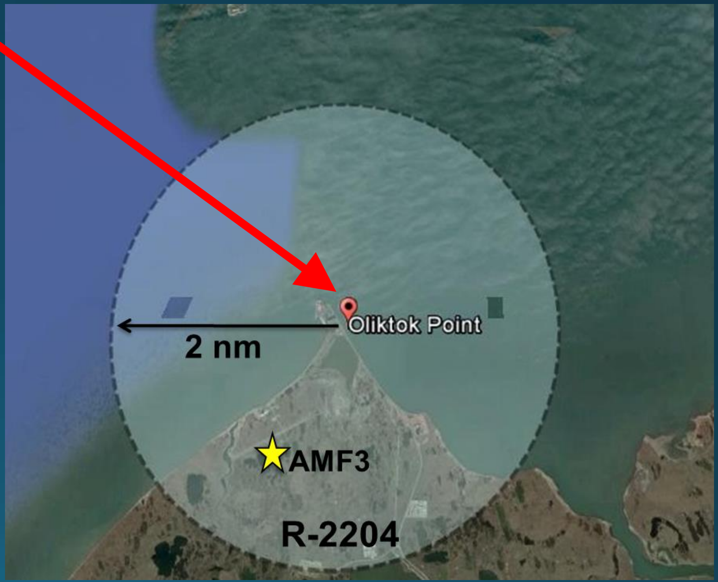
The DOE Office Of Science/BER ARM Program Understanding Critical Atmospheric Processes



Sandia-Managed DOE/ARM-North Slope of Alaska Facilities

- **ARM-NSA and Adjacent Arctic Ocean Research Facilities:**
  - **Barrow**: to measure ocean-land-atmosphere interface conditions
  - **Atqasuk**: to measure land-atmosphere interface for comparison with Barrow measurements for differences between land and shore conditions (inland)
  - **Oliktok and Third ARM Mobile Facility**: to measure ocean-land-atmosphere interface; use of R-2204 and W-220 for aerial atmospheric measurements



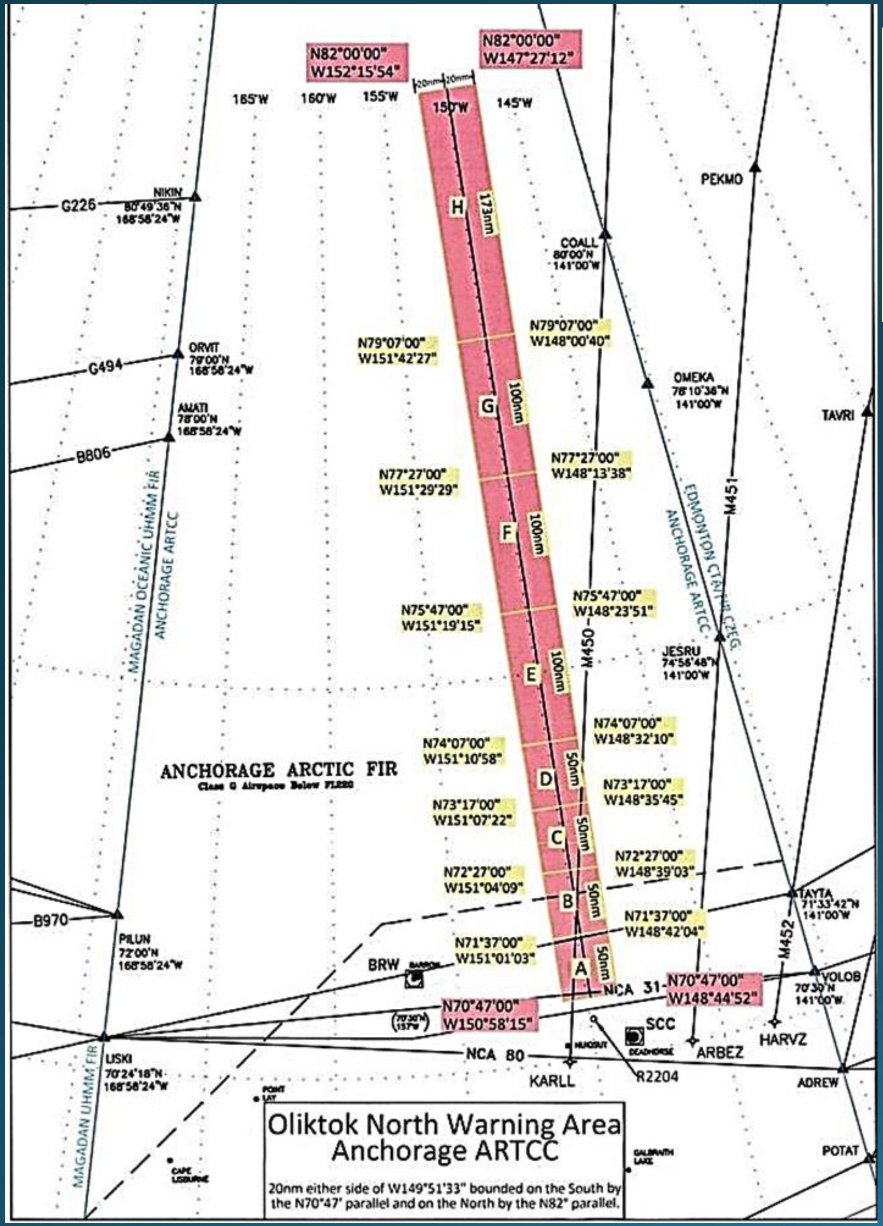


Barrow
1997 - present

Atqasuk
1999 – 2010

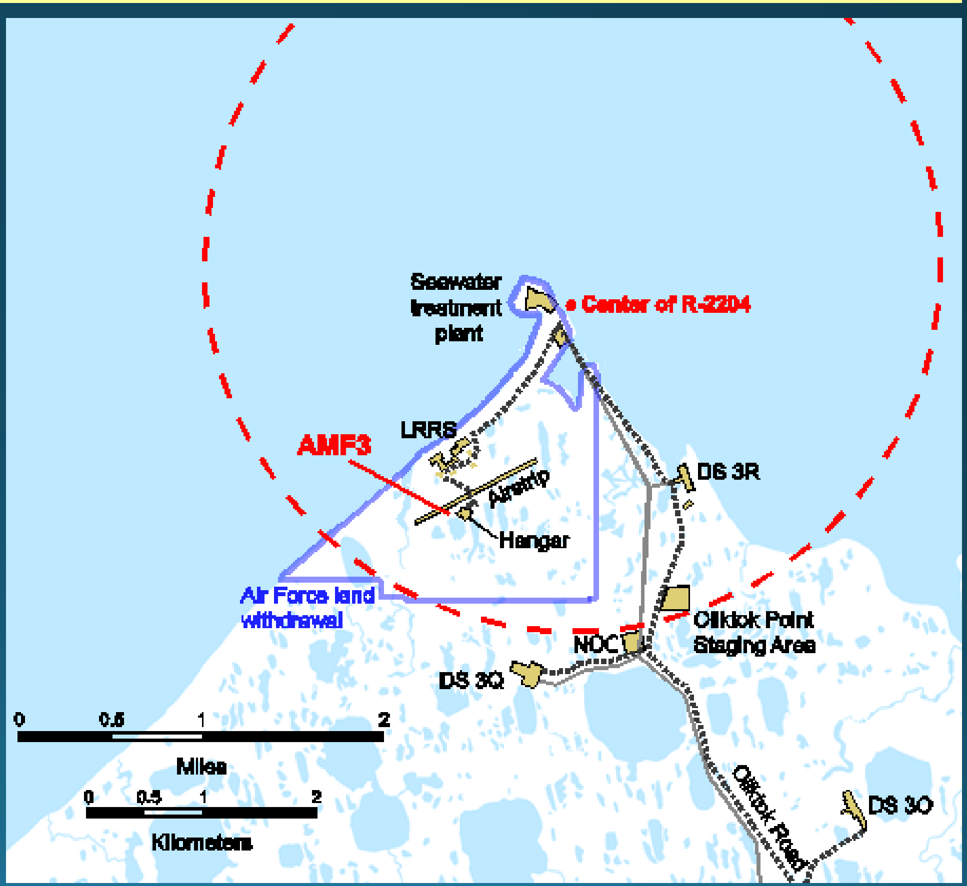
Oliktok (AMF-3)
2013 - present

Sandia manages special-use airspace for DOE

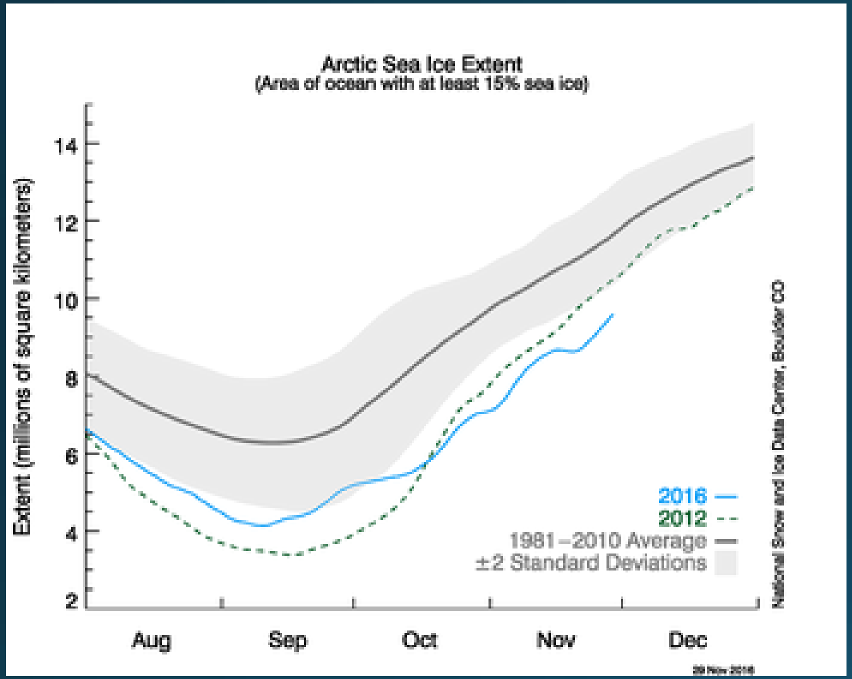


“We need ***a U.S. Arctic location*** for exercises to employ networked multiple autonomous systems” –

Dr. Philip McGillivary, USCG/Stanford



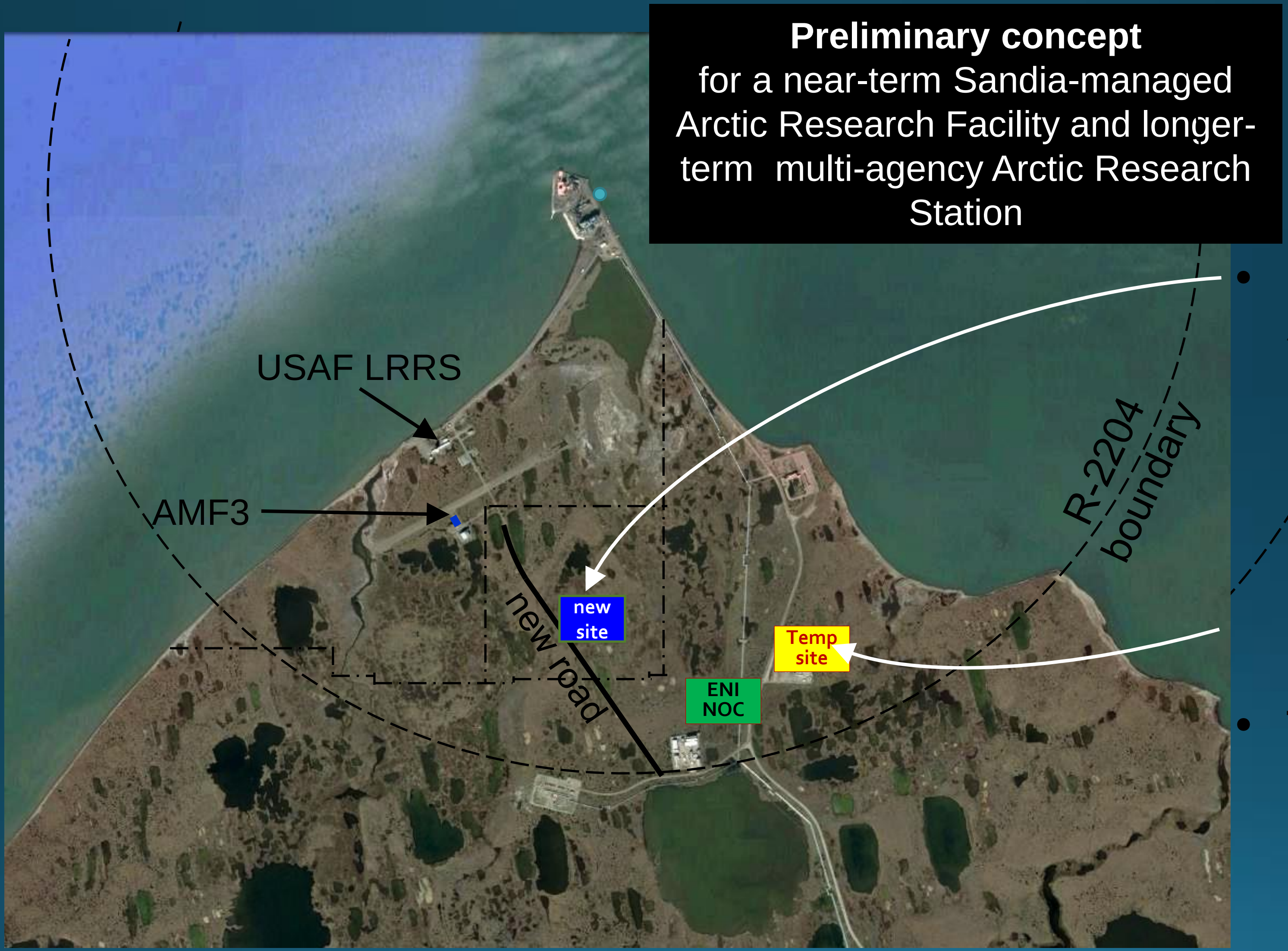
Arctic Sea Ice Extent and National Security Issues



In October 2016, Arctic sea ice extent averaged 6.40 million square kilometers (2.5 million square miles), the lowest October in the satellite record. This is 400,000 square kilometers (154,400 square miles) lower than October 2007, the second lowest October extent, and 690,000 square kilometers (266,400 square miles) lower than October 2012, the third lowest. The average extent was 2.55 million square kilometers (980,000 square miles) below the October 1981 to 2010 long-term average.

As of early November, extent remains especially low within the Beaufort, Chukchi, East Siberian, and Kara Seas (Source: National Snow and Ice Data Center, 30 Oct 2016).

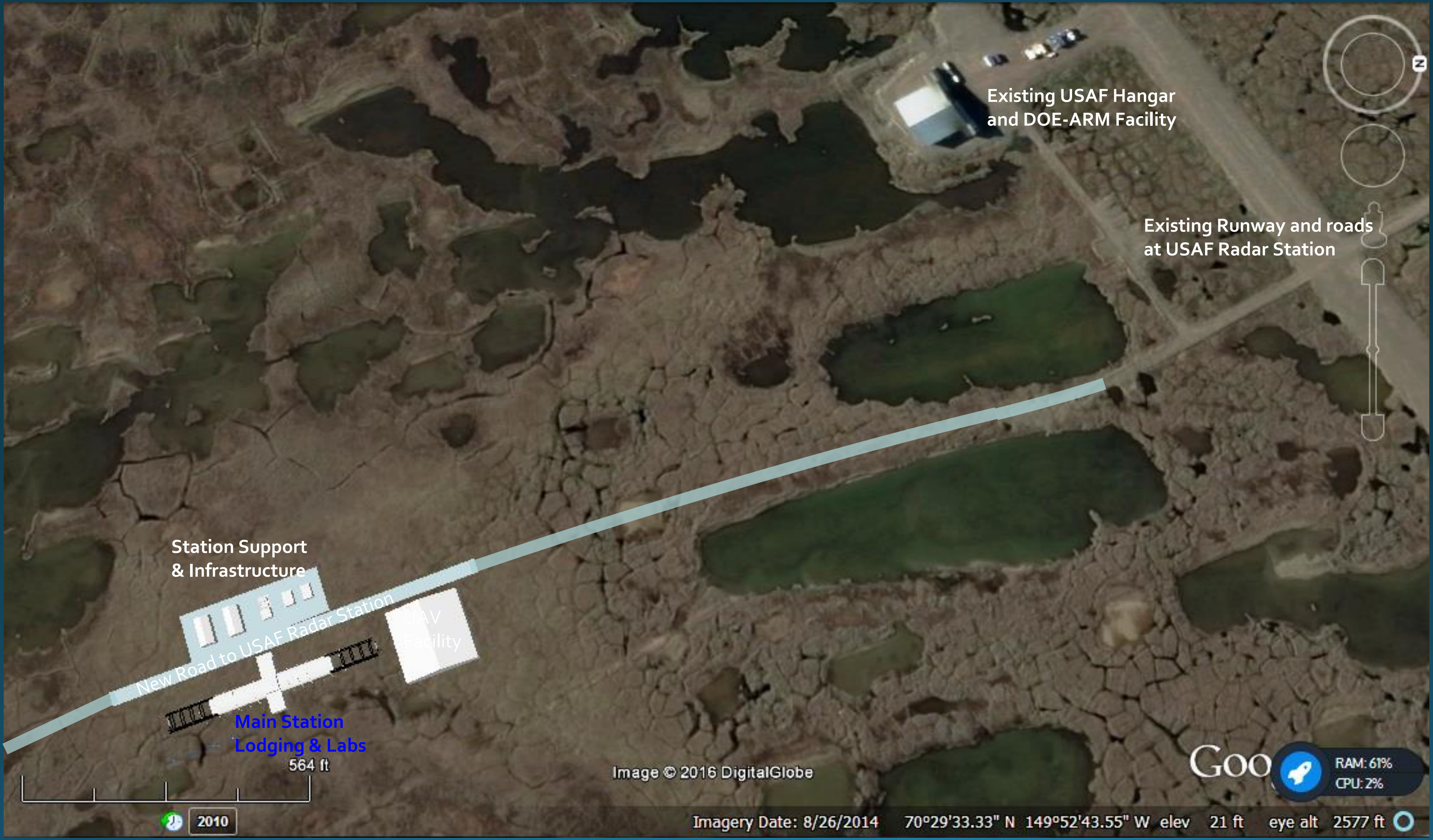
Future Plans: Arctic Research Station



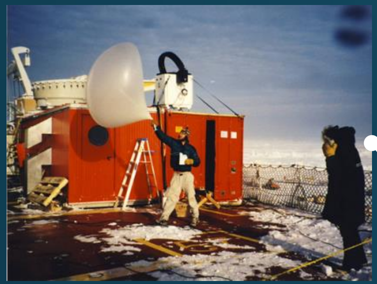
- **Permanent** ARM Arctic Research Station proposed for ~2020 start
- **Temporary** UAS Facility planned for 2017 start

Proposed ARM/Multi-agency Arctic Research Station
** CONCEPTUAL PRELIMINARY DESIGN SCHEME **

June 2016

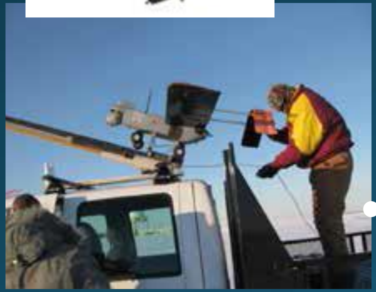


Unmanned aerial systems (UAS)









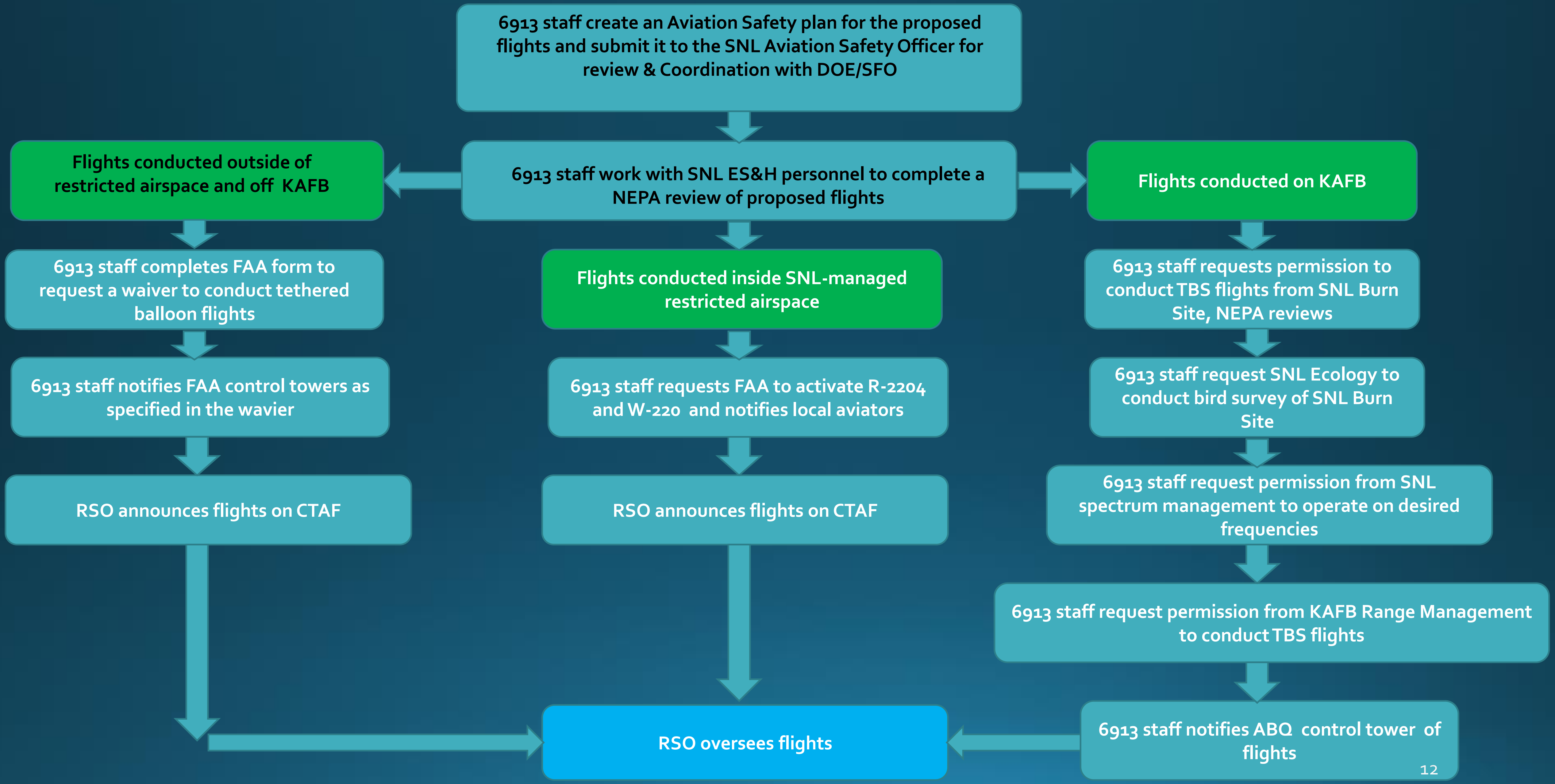
- **Past Campaigns:**
  - Aerosonde Project (2001, Barrow) with NSF and Aerosonde; using Aerosonde platform
  - IPASRC II (2001, Barrow) with UAF; included radiosondes using Vaisala RS-80 sonde
  - Simultaneous Aerosonde-Radiosonde IOPs (2002, Barrow) with ANL and NSF; using Vaisala sondes and Aerosonde platforms
  - ARM Radiosondes for NPOESS/NPP Validation (2012-15) with UWisc
  - AIRS Validation radiosondes (2002-07, Barrow) with NASA, PNL and ANL; using Vaisala sondes
  - Mixed-Phase Arctic Cloud Experiment (M-PACE, 2004, Barrow, Atqasuk, Oliktok, Toolik Lake) with UAF, PSU, UIUC, UND, UWisc, PNNL and NOAA; using Vaisala sondes and ARM-Proteus platforms
  - Arctic Lower Troposphere Observed Structure (ALTOS, 2010) with SPEC, PSU, Scripps and UAF; using SPEC 78m^3 He-filled moored balloon
  - UAS Test Maneuvers (2012, Oliktok) with NMSU; using BAT-3 and Aeryon Scout
  - Marginal Ice Zone Observation & Process Experiment (MIZOPEX, 2013-16, Oliktok) with NASA, UAF and CU; using NASA Sierra, Datahawk and ScanEagle platforms
  - Coordinated observations of the Arctic lower atmosphere (COALA, Oct 2014, Oliktok) with CIRES/UC-Boulder; using DataHawk platform.

Unmanned aerial systems (UAS) - TBS

- Tethered Balloon Systems
  - Can operate in clouds
  - Enclosed winch or launch platform
  - 35 m^3 helikites
    - 30 lb payload, up to 2,000' AGL
  - #28 Skydoc aerostat and launcher
    - 80 lb payload, up to 6,000' AGL
  - Limitations:
    - crew availability
    - ice loading
    - helium/gas diffusion
    - sensor battery life in cold
    - launch/retrieval only if sustained surface winds <30 mph
    - need Restricted Airspace or FAA waiver to operate TBS >150' AGL
    - must have emergency deflation device on balloon and streamers attached to the tether

AGL = Above Ground Level

TBS Procedural Flow Diagram



Aviation Safety Plans and Approvals Required

- Operations Plan for: Tethered/Moored Balloon and Helikite Operations at Oliktok Point, Alaska and Sandia National Laboratories, New Mexico, December 1, 2014
- Operations at Oliktok Point are also governed by US Air Force safety and security requirements at the USAF Long Range Radar Station on which the DOE ARM-3 facility is located
- TBS operations are performed such that unacceptable consequences are avoided and operations are conducted in accordance the following:
  - PHS: SNL10A00314-004, Moored Balloon Operations at Oliktok Point Alaska
  - PHS: SNL04A00744-010, Climate research Facilities on the North Slope of Alaska/Adjacent Arctic Ocean
  - ES&H SOP: Atmospheric Radiation Measurement Climate Research Facility/North Slope of Alaska/Adjacent Arctic Ocean (ACRF/NSA/AAO) Project Operating Plan
  - NEPA: SNA10-0384
  - JSA IN No.- JSA07262012-A
- Time required to obtain all permissions necessary to operate TBS has ranged from 3 months – 1 year
  - FAA approval process is typically < 1 month
- R-2204 at Oliktok Point, AK may only be activated for 75 days annually under current FAA rules
- UAS and TBS Operations Safety Plan currently under Revision for Updates, Part 107 Compatibility

Unacceptable Consequences for Unmanned Aerial System (UAS) Operations

- Death or debilitating injury to members of Sandia's workforce, Users, military personnel, or members of the public
- Adverse impact to the environment as defined by the State of Alaska or DOE
- Loss of access to the Oliktok Point or Barrow facilities
- Cancellation of permits
- Loss of Sandia's ability to participate in the DOE North Slope of Alaska ARM program (brings in thresholds and limits)

Unacceptable Consequences with Programmatic Thresholds

- Loss of the capability to conduct operations exceeding 6 months.
- Loss of electrical power for more than 1 week.
- Threshold loss of UAS vehicles and TBS (loss requirement from DOE program management, note difference for *manned aircraft*).
- In addition to the above unacceptable consequences for all UAS operations, project and user-specific unacceptable consequences shall be defined for each project and experiment, as appropriate. Such unacceptable consequences may include, for example, loss of non-expendable user equipment or instruments (e.g. dollar value basis).

Safety Challenge: Roughly 20 Years of Safety and Operations Documentation and Training

- ES&H SOP: Atmospheric Radiation Measurement Climate Research Facility/North Slope of Alaska/Adjacent Arctic Ocean (ACRF/NSA/AAO) Project Operating Plan
- Visitor Briefing and Visitor's Guide- Oliktok Point, North Slope of Alaska, Oct 2016
- Unacceptable Consequences For Unmanned Aerial System (UAS) Operations At Oliktok Point, Alaska May 6, 2013
- Barrow Balloon Operations Aviation Safety Plan, AV 16-12, 5/23/16
- Barrow Balloon Flight Operations, Ver 1.0, May 2016
- 6913-TWD- Tethered/Moored Balloon Operations, Dec 2014, Rev 1
- PHS: SNL04A00744-010, Climate research Facilities on the North Slope of Alaska/Adjacent Arctic Ocean
- PHS: SNL10A00314-004, Moored Balloon Operations at Oliktok Point Alaska
- NEPA: SNA10-0384
- FAA-approved R-2204 activation for Oliktok TBS/UAS
- 14CFR101 Moored Balloons, Kites, Amateur Rockets, and Unmanned Free Balloons
- JSA IN No.- JSA07262012-A
- **ES&H Awareness: ESH100 required.**
- **Hazardous Waste and Environmental Management Training ENV112 required.**
- **Cold** Weather Hazards Plan**,** ACRF/NSA/AAO, Aug 2010, Rev 10
- Bear Plan ACRF/NSA/AAO, August 2010, Rev 9
- **Operation and Maintenance Procedures for the CART RAMAN LIDAR System,** J. Goldsmith and F. Blair, SNL, Nov 15, 2016
- Material Handling: PKX155 Basic Hazardous Materials Driver Training required.
- **Material Handling:** FKL153 Forklift Operator and Hands on Training required.
- Material Handling: PKX150 Basic Load Securement Training for Drivers and Traffic Personnel required.
- **Electrical Safety**: *NFPA 70E* All equipment meets Nationally Recognized Testing Laboratories (NRTL) requirements
- **Fall Protection**: *OSHA 29 CFR 1926, Subpart M – Fall Protection*.
- **Chemical Safety Training CHM100 required**
- **Elevated work**: *OSHA 29 CFR 1910.26*.
- Ladder Safety Awareness Training LSA100 required
- **Machine Guarding/Hand Tools:** *OSHA 29 CFR 1910, Subpart P – Hand and Portable Powered Tools and Other Hand-Held Equipment and OSHA 29 CFR 1926, Subpart I – Tools – Hand and Power.*

The Engineered Safety Process

Engineered Safety Principles:

- Safety-by-Design Intent - Safety is most effectively and efficiently achieved by designing it into the system at the conceptual or initial planning stages.
- Define Unacceptable Consequences – Critical thinking requires a thorough understanding of the technical basis of the work that leads to seeking out failure modes that can cause accidents to occur.
- Understand Technical Basis – Emphasis is placed on implementation of engineered controls that eliminate hazards rather than the mitigation of hazard impacts.
- Consequence Assessment Approach – Evaluates failure modes without regards to the probability of failure.
- Identify and Control Energy Sources
- Positive Verification – MOW affirms that their part of the system is in the state intended for safe operation.

The Engineered Safety Process for ARM North Slope Operations

The Sandia ARM team met for two days to review all aspects of the program, projects, and special conditions that apply to working at the North Slope.

The draft Engineered Safety documents were reviewed, edited, reviewed again by the interdisciplinary team and submitted for managerial signatures.

Ongoing reviews and lessons-learned activities.

Sandia National Laboratories – Work Planning and Control – Criteria for Safe Design and Operation

Identify Scope and Plan Work

Department Number & Title	6913 - ARM Program - Climate Research facilities on the North Slope of Alaska - Adjacent Arctic Ocean
Project/Activity Name	Climate Research on the North Slope of Alaska

Customer Contact Information (Optional)

Organization or Agency **Contact Name/Role** **Phone**	**Email**

Roles and Responsibilities

Work Planner	Daniel A Lucero & Carolyn Kirby
Work Planning Team	*The Level I manager shall establish, or assist the delegated Work Planner in establishing, an interdisciplinary team consisting of subject-matter experts necessary to competently identify hazards and evaluate key factors.*

Name	Organization	Role or Area of Responsibility
Mark Ivey	6913	ARM NSA Program Manager
Daniel Lucero	6913	Barrow Site Manager
Dean Archuleta	6913	Barrow Operations Manager
Fred Helsel	6913	Oliktok Site Manager
Bruce Edwardson	6913	Oliktok Operations Manager
Todd Houchens	6913	ARM NSA Radar & Lidar Tech
Dari Dexheimer	6913	UAS & TBS Operations

North Slope Introduction | 1,2) Scope-Oprt Envlp-AcptWrk | 3) IDT Rev | FMA | Safety Case | 5) JSA | 6,7) Readiness-AuthWrk | 8,9) Closeout-Lessons Lrnd

Our Engineered Safety Review: Major Categories

Initial Hazard Identification

Identify the predominant hazards associated with this work.

An optional tool to assist with this task is the:	Work Planning Walk-down Checklist.
Lasers EMF hazards Cryogenic hazards Thermal hazards - Extreme temperatures and weather conditions Firearms - Use of guns for protection Electrical Mechanical - rotating equipment, heavy equipment Slips, trips & falls Animal hazards Driving in Snow and Ice Use of ATV's and Snow mobiles Travel-related hazards: Fatigue, ergonomic	

Observable Benefits from Our Engineered Safety Reviews

- Immediate engagement of staff in willingness to speak up about safety and empowered “fresh look with new eyes”
- Helped orient new staff
- Re-framed existing ES&H issues, e.g. firearms
- Helped us handle an escaped balloon incident July 2016

Example: The Escaped Tethered Balloon at Oliktok, 2016

- A 74m³ helium-filled balloon operated by Sandia escaped from its mooring at approximately 2:40pm AKDT on July 27, 2016 within Restricted Area R-2204 at Oliktok Point, North Slope of Alaska.
- There were no human errors, management system failures, or shortcomings that were precursors or contributing causes to the event. The root cause of the event was a microburst that produced a load on the balloon exceeding design specifications.
- The emergency deflation device (EDD) operated as designed, causing the balloon to become deflated and to descend into the Arctic Ocean approximately 60 km NE of the launch site.
- The FAA and local aviators were immediately notified and FAA posted a Notice to Airmen (NOTAM).
- Relevant Alaska airport control towers were notified by phone
- Emergency deflation device activated automatically when balloon exceeded 6,500’ AGL

Engineered Safety: The Escaped Balloon Event

- Prior to the escape, wind speeds indicated by instruments on the tether were 6 to 10 m/s (22.4 mph), well within the balloon operating limit of 13 m/s.
- The tether was rated and tested for 1,450 kg strength, enough to handle 36 m/s.
- The balloon operating limit of 13 m/s was selected to provide a 4.5x safety factor.

Actions after the event:

- The existing 1450 kg-rated tether was replaced with 2500 kg-rated tether (40 m/s).
- To avoid potential microbursts, flights will be restricted based on meteorological conditions. Input requested from Site Science Team at CU/Boulder.
- An anemometer was added to the TBS ground station in order to view real-time wind gusts.
- Other opportunities for improvement were identified and implemented (tracking device).
- Weeks later, a balloon reported to FAA that was observed in the Arctic Ocean and subsequently reported to Sandia was not the Sandia balloon.

Engineered Safety Applied to the Escaped Balloon Event

- Safe-by-Design Intent
  - Balloon and winch system specified and commercially procured
  - GPS-activated Emergency Deflation Device procured
- Define Unacceptable Consequences
  - Sources identified that could result in an unacceptable consequence
    - Failure of EDD
    - Failure of winch
    - Failure of tether
    - Collision with aircraft or structures
    - Dropped instrument/payload
- Understand Technical Basis
  - Evaluate the load on the tether taking into account the balloon lift, payload weight, wind speed.
  - Size the winch and tether to provide a 4.5x safety factor

Engineered Safety Applied to the Escaped Balloon Event, Continued

- Consequence Assessment Approach
  - Identify the conditions that would result in an unacceptable consequence
    - Wind speed greater than 13m/s @ 15C
    - "Intruder" aircraft
    - Tether failure
    - EDD failure
- Identify and Control Energy Sources
  - Intruder aircraft: R-2204 activation; Aviation Radio for traffic advisory; RSO
  - No TBS operations when wind speed approaches 13 m/s
  - Triple attachment to the tether of instruments weighing > 5 lbs.
- Positive Verification
  - Winch tested against load specification prior to acceptance
  - Tether tensile strength tested by a commercial laboratory
  - EDD tested to ensure activation at preset horizontal distance from launch point
  - Pre-flight inspection of balloon, tether, winch, and instruments to be attached to the tether.
  - Notification to NSA Aviation Community of planned TBS operations
  - FAA posted NOTAM
  - Announcement of TBS operations on aviation Common Traffic Advisory Frequency
  - Continuous monitoring of wind speed from instruments on the tether.
  - Independent verification of instrument attachment to the tether.

Bottom Line: Why did the Balloon Escape?

- The microburst was a beyond-design-basis event
  - Load on the tether exceeded the 4.5X safety factor
  - Microbursts are extremely unlikely on the NSA
- Design criteria and administrative control added for TBS operations
  - Atmospheric conditions that are precursors to microbursts researched
  - Those conditions implemented as administrative controls to stop (or prevent) TBS operations

Conclusion (from incident reviewers): We had included the escaped balloon in our engineered safety analysis, developed response plans, and executed those plans when the event happened.

Opportunities for Improvement

- Frequent Visits and Site Surveys by Sandia Safety Staff, Coordinators, Safety Engineering (Improvements in "Advance")
- Visits and Reviews by Senior Sandia and DOE management (Helps in Dealing with Issues and Events)
- Communications, Internal and External, for Better Safety Reviews
- Training for Off-Site Staff and Contractors
- Better Internal Teaming
- Lessons Learned Analyses
- Empowering Staff to Speak up
- Dealing with Change and New Requirements

On-Going Challenges for Safe ARM Operations on the North Slope

- Complexity of Operations, Remote Operations
- Multi-lab Program, DOE "User Facility" Model, ARM Program Requirements and Communications
- Wide Variety (and growing) of DOE Labs, Federal Agencies, Academic, and Industry Collaborators
- Evolving and Legacy ES&H Documentation and Policies
- Evolving DOE Policies for Unmanned Aircraft
- Unique Cultural, Physical, Financial Aspects of Arctic Operation
- Firearms, Cold Weather, Procurement and Contracting Issues
- Land Use Agreements, Leasing
- "10CFR851"

Credit for Our Success: Outstanding, Dedicated, and Committed Staff at Sandia, Barrow, and Oliktok!