Meteorological Joint Observations for Live Nuclear Reconnaissance (MJOLNuR)

Volume 2: Technical Volume

1. Identification and Significance of the Problem or Opportunity.

The Urgency: Rapid Response in the Face of Nuclear Threats

In the critical aftermath of an atmospheric nuclear detonation, every second counts. The Defense Threat Reduction Agency (DTRA) must swiftly detect and analyze the ensuing nuclear plume to protect military personnel, civilian populations, and vital infrastructure. These plumes are complex amalgams of vaporized materials, radionuclides, and particulates ranging from larger fallout particles to ultrafine aerosols like PM2.5. The unpredictable dispersion of these hazardous materials poses immediate and long-term risks, making timely and accurate information paramount.

Current detection systems, while reliable, lack the agility and advanced integration capabilities required to process the vast influx of data from modern sensors and satellites. The United States Atomic Energy Detection System (USAEDS), for instance, provides essential data but cannot fully leverage recent advancements in Earth Observation (EO) satellites, machine learning models, and data fusion technologies. This gap leaves DTRA without the comprehensive situational awareness needed for decisive action in the face of nuclear threats.

Our Vision: MJOLNuR—Revolutionizing Nuclear Plume Detection and Forecasting

Imagine a scenario where the instant a nuclear detonation is detected, an advanced system springs into action. Dormant until that critical moment, it automatically begins aggregating all available data related to the event's location. It fuses this information to construct the most accurate digital twin of the plume possible, given the real-time data at hand. Simultaneously, it gathers essential weather observations for data assimilation into a high-precision forecasting model. As the process unfolds, it generates detailed forecasts of the fallout dispersion, streaming this critical information directly to military units and civilian agencies. This is the Meteorological Joint Observations for Live Nuclear Reconnaissance (MJOLNuR).

How MJOLNuR Transforms the Response Paradigm

1. Rigorous Scientific Approach Enhancing Confidence

MJOLNuR employs a scientifically tested methodology to establish a direct connection between remote sensing products and specific fallout materials. By conducting an exhaustive analysis of plume constituents—ranging from vaporized soil and building materials to radionuclides—it categorizes these materials based on detectability factors like particulate size, density, and optical properties. This rigorous approach ensures that the data collected from satellites and sensors is accurately correlated with the actual plume characteristics, enhancing the confidence of decision-makers in the system's outputs.

2. Two-Stage Process for Superior Accuracy

- **Stage One: Digital Twin Creation through Data Fusion**
  Upon detection of a nuclear event, MJOLNuR rapidly assimilates data from multiple sources—including high-resolution EO satellites equipped with multispectral and hyperspectral sensors, forecasting models, and any available ground-based observations. By fusing this data, it constructs a dynamic digital twin of the nuclear plume, accurately representing its current state in terms of composition, height, extent, and movement.
- **Stage Two: High-Precision Forecasting with Advanced Models**
  The digital twin is then integrated into a cutting-edge weather forecasting model, such as Google's GraphCast—a machine learning model known for its speed and precision. By initializing the model with the digital twin, MJOLNuR generates highly accurate predictions of the plume's downwind rise height and potential fallout dispersion under various aerosol loadings. This enables proactive planning and response, providing ample warning to maneuver units and implement protective measures.

3. Seamless Integration and Dissemination through Standardized Outputs

MJOLNuR ensures that all generated data is formatted in compliance with established standards, facilitating quick and easy ingestion into the systems of allied organizations:

- **Joint Enterprise Data Interoperability (JEDI):** By adhering to JEDI standards, MJOLNuR promotes interoperability across Department of Defense (DoD) platforms, ensuring that data flows smoothly between systems without loss of fidelity.
- **National Information Exchange Model (NIEM):** MJOLNuR maps its data outputs to NIEM schemas, enabling efficient information exchange with federal agencies and supporting interagency collaboration during nuclear events.
- **Joint Center for Satellite Data Assimilation (JCSDA):** Incorporating data assimilation techniques from JCSDA ensures that satellite data is standardized and can be seamlessly integrated into forecasting models.

Delivering Critical Information Where It's Needed Most

- **Real-Time Data Streaming to Stakeholders**
  As MJOLNuR generates forecasts, it streams data directly to various organizations in standardized formats. Military units receive actionable intelligence to maneuver and avoid contaminated areas. Civilian agencies gain the information necessary to issue evacuation orders or shelter-in-place directives, safeguarding public health.
- **Visualization and Decision Support Tools**
  MJOLNuR includes graphical display tools that present complex data in an intuitive manner. Users can visualize plume trajectories, dispersion patterns, and hazard areas, supporting both immediate decision-making and strategic planning.

Conclusion: Empowering DTRA with Next-Generation Capabilities

MJOLNuR represents a transformative solution that addresses the urgent need for rapid, accurate nuclear plume detection and analysis. By leveraging advancements in remote sensing, data fusion, and machine learning, it provides DTRA with enhanced situational awareness and predictive capabilities. The system's rigorous scientific foundation, coupled with its innovative two-stage process and commitment to interoperability, ensures that DTRA is equipped to respond effectively to nuclear threats.

As we embark on Phase I, our focus is on laying the groundwork for this vision. By identifying the most appropriate satellite products and establishing the feasibility of our approach, we set the stage for a system that not only meets current challenges but is adaptable to future technological advancements. MJOLNuR is more than a tool; it's a strategic asset that strengthens national security and enhances readiness in the face of nuclear threats.

2. Phase I Technical Objectives.

While our long-term vision for MJOLNuR is to provide DTRA with a comprehensive, integrated platform for nuclear plume detection and analysis, Phase I focuses on foundational research and evaluation tasks essential for realizing this goal. We recognize that achieving the full capabilities of MJOLNuR is a multi-phase endeavor. Therefore, the Phase I objectives are specifically designed to determine the feasibility of our proposed approach by identifying the most suitable data sources and modeling tools for plume detection and characterization. The objectives are listed below in order of priority.

Objective 1 - Survey Candidate Products

- **Questions To Be Answered:**
  - What is the full list of products to be analyzed?
  - What are the attributes of these products, including spatial resolution, temporal resolution, reliability, data output, category (Level 1, Level 2, forecast model output), etc?
- **Purpose:**
  - In order to conduct the analysis necessary for the final deliverable of *"a determination of which satellites products are most appropriate for deriving plume characteristics near a nuclear detonation event and estimating downwind*

plume rise height under multiple aerosol loadings." we must first establish an exhaustive catalog of products to be analyzed.

Objective 2 - Plume Materials Detectability Literature Review

- **Questions To Be Answered:**
    - What materials are nuclear plumes composed of?
    - How can those materials be categorized for detectability? (i.e. by particulate size, density, optical properties, etc)
- **Purpose:**
    - Understanding the material composition of nuclear plumes and the detectability of those materials will be a foundational step in making determinations for the suitability of various satellite products.

Objective 3 - Assess Level 1 Products

- **Questions To Be Answered:**
    - Which Level 1 satellite products would be most useful for global, near real time, plume characterization?
- **Purpose:**
    - Satellite data is typically categorized into Levels 0 through 4. Level 0 (L0) is raw instrument data which can be difficult to process. L1 is derived from L0 and has been calibrated and processed to sensor units such as radiance, brightness temperature, etc. This level is typically accepted as the first 'usable' and raw form of the data. Conducting an assessment at this level of data requires making a connection from channel (or wavelength) directly to the material of interest. The complete list of evaluation criteria is as follows:
        - **Spectral Capabilities/Sensor Types**: Evaluate the suitability of sensors for detecting constituent plume materials.
        - **Data Availability and Accessibility:** Availability of data and any associated costs or restrictions.
        - **Spatial Resolution:** Ability to detect plume features at required spatial scales.
        - **Temporal Resolution:** Frequency of data updates suitable for near-real-time monitoring.
        - **Data Latency:** Time lag between data acquisition and availability.
        - **Coverage Area:** Geographic coverage relevant to operational needs.
        - **Reliability and Continuity:** Operational status and reliability of data streams.
        - **Historical Data Availability:** Availability of historical data for validation and analysis.

Objective 4 - Assess Level 2+ Products

- **Questions To Be Answered:**
    - Which Level 2+ satellite products would be most useful for global, near real time, plume characterization?
    - Can a scientifically justifiable connection be made between Level 2+ data and the materials of interest?
- **Purpose:**
    - Level 2 (L2) products are derived from L1 products that have been processed to geophysical quantities of interest, e.g. aerosol optical depth, cloud top height, hot spot detection, etc. If any of these derived products are relevant for nuclear plume analysis then using them instead of their L1 counterparts could improve the timeline for integration by removing the necessity for generating an in-house equivalent directly from the L1 data. The evaluation criteria listed above will also be used to rank order the Ll 2 products.

Objective 5 - Assess Forecasting Products

- **Questions To Be Answered:**
    - Which forecasting products would be most useful for global, speed of need, downwind plume rise height and general fallout dispersal estimates and forecasts?
    - What are the hardware requirements for running these models?
    - Can the data assimilation be modified to manually insert plume characteristics for both historical and operational purposes?
- **Purpose:**
    - While the solicitation does not specifically mention forecasting models, Aulendur recommends including them in the set of products to be analyzed. Our vision for MJOLNuR splits the problem into 2 components. Analysis and Forecasting. Analysis of the plume is a data fusion effort with the objective of creating a ‘digital twin’ of the plume as accurately as possible. However, once dispersion begins, it is unclear for how long the direct detection (and therefore analysis) of the fallout will be possible. Therefore in order to *“give sufficient warning so units can maneuver and avoid areas of impending or actual residual radiation.”* it will be imperative that this digital twin can be used as a starting point for the Forecasting step. By assessing forecasting models such as GALWEM, WRF, HRES, or GraphCast for their ability to ingest the digital twin and predict the dispersion of materials, we ensure MJOLNuR will be designed from the ground up with the ability to provide timely warning to the warfighter.

Objective 6 - Assess the Feasibility of Developing an Operational Application

- **Questions To Be Answered:**
    - Are the project goals achievable given the results of the analyses?
    - How will the products be brought together to provide a scientifically justifiable analysis and forecast product?
    - What software engineering and scientific challenges will the project face?
- **Purpose:**
    - While the other objectives focus on the scientific viability of this effort, this objective is related to how those analyses will be used to produce a usable, operational application.

3. Phase I Statement of Work.

To lay the groundwork for MJOLNuR's development, we have designed a series of tasks that systematically address the key components required for effective nuclear plume detection and analysis. Each task builds upon the previous one, ensuring a comprehensive evaluation of available resources and technologies. Our focus is on identifying optimal data sources, evaluating modeling tools, and ensuring compatibility with DoD standards, all while exploring novel and emerging technologies that could enhance MJOLNuR's capabilities. Project and task timelines are measured in weeks from the date of Contract Award (CA).

Task 1: Survey Candidate Products

Objective:
Establish an exhaustive catalog of satellite and forecasting products relevant to nuclear plume detection and characterization.

Subtask 1.1: Comprehensive Data Collection

- **Timeline:** CA to CA + 4 weeks
- **Method:**
  Conduct a systematic search of satellite databases, scientific literature, and industry resources to compile a list of all potential satellite products, both Level 1 and Level 2+, as well as relevant forecasting models.
- **Activities:**
    - Utilize databases from agencies such as NOAA, NASA, ESA, WMO, and commercial satellite providers.
    - Identify international satellites and emerging technologies (e.g., CubeSats, nanosatellites).
    - Include both well-known and obscure data sources to ensure a comprehensive survey.

Subtask 1.2: Product Attribute Documentation

- **Timeline:** CA + 2 weeks to CA + 6 weeks
- **Method:**
  For each identified product, document key attributes such as spatial and temporal resolution, data latency, coverage area, reliability, data accessibility, and category level.

- **Activities:**
  - Create a standardized template for recording product attributes.
  - Engage with data providers to obtain detailed specifications and access information.

Deliverables:

- **D1:** A comprehensive catalog of candidate satellite and forecasting products, including detailed attributes for each product.

Task 2: Plume Materials Detectability Literature Review

Objective:
Understand the material composition of nuclear plumes and assess the detectability of these materials using remote sensing technologies.

Subtask 2.1: Nuclear Plume Composition Review

- **Method:**
  Conduct a focused review of key scientific literature, research reports, and historical data on nuclear plume composition and remote sensing detection methods.
- **Activities:**
  - **Analyze Nuclear Plume Composition:**
    - Review studies on nuclear detonations and fallout to identify primary plume constituents, including radionuclides (e.g., Cesium-137, Iodine-131), vaporized metals, soil particles, and combustion byproducts.
    - Understand the physical and chemical forms of these materials, their particle size distributions (from nanometer-sized aerosols to larger particulate matter), and their dispersion mechanisms in the atmosphere.
  - **Identify Detectability Factors:**
    - Categorize plume materials based on properties affecting detectability:
      - **Particulate Size:** PM2.5 (particles ≤ 2.5 μm), PM10 (particles ≤ 10 μm), and larger debris.
      - **Optical Properties:** Absorption and scattering characteristics in various electromagnetic (EM) spectral bands.
      - **Thermal Properties:** Emissivity and thermal signatures detectable in infrared wavelengths.
      - **Chemical Composition:** Presence of specific elements or compounds that may have unique spectral features.

Subtask 2.2: Detectability Review

- **Method:**
  Map the properties of plume materials to relevant remote sensing detection methods and sensor capabilities.
- **Activities:**
  - **Spectral Band Assessment:**
    - Determine which EM wavelengths are most effective for detecting specific plume constituents.

        - Identify spectral signatures associated with radionuclides and particulate matter, focusing on bands used by existing satellite sensors.
    - **Sensor Evaluation:**
        - **Passive Optical Sensors:**
            - Assess capabilities for detecting aerosols and particulate matter through measurements of reflected sunlight in the visible and near-infrared (VNIR) bands.
        - **Thermal Infrared (TIR) Sensors:**
            - Evaluate effectiveness in detecting thermal anomalies and hot plumes immediately after detonation.
        - **LIDAR Systems:**
            - Consider the use of active sensors like CALIPSO for vertical profiling of aerosol layers and plume height estimation.
        - **Hyperspectral Sensors:**
            - Explore potential for detailed spectral characterization of plume constituents.
    - **Detection Techniques:**
        - Review existing algorithms for aerosol optical depth retrieval, plume edge detection, and particulate matter estimation.
        - Examine methodologies from analogous applications, such as volcanic ash detection and wildfire smoke monitoring, for potential adaptation.

Deliverables:

- **D2:** A concise report summarizing:
    - **Composition of Nuclear Plumes:**
        - Overview of primary constituents, their sources, and physical properties.
    - **Detectability Categorization:**
        - Classification of materials based on factors affecting remote sensing detection.
    - **Remote Sensing Techniques:**
        - Identification of the most effective spectral bands and sensor types for detecting specific plume materials.
    - **Recommendations:**
        - Guidance on which detection methods are most promising for integration into MJOLNuR.
    - **Key References:**
        - Glasstone, S., & Dolan, P. J. (1977). *The Effects of Nuclear Weapons*. U.S. Department of Defense and U.S. Department of Energy.
        - Prata, A. J. (1989). *Observations of Volcanic Ash Clouds in the 10–12 µm Window Using AVHRR/2 Data*. International Journal of Remote Sensing, 10(4-5), 751–761.
        - Remer, L. A., et al. (2005). *The MODIS Aerosol Algorithm, Products, and Validation*. Journal of the Atmospheric Sciences, 62(4), 947–973.

Task 3: Assess Level 1 Products

Objective:
Evaluate Level 1 satellite products for their utility in global, near-real-time plume characterization.

Subtask 3.1: Product Selection

- **Method:**
  Based on the catalog from Task 1 and insights from Task 2, select Level 1 products for detailed evaluation.
- **Activities:**
  - Prioritize products with suitable spectral capabilities identified in Task 2.
  - Ensure a diverse representation of geostationary and polar-orbiting satellites.

Subtask 3.2: Evaluation Against Criteria

- **Method:**
  Assess each Level 1 product using the established evaluation criteria.
- **Activities:**
  - Analyze spectral capabilities, data availability, spatial and temporal resolution, data latency, coverage area, reliability, and historical data availability.
  - Document findings in a comparative matrix for easy reference.

Subtask 3.3: Data Access and Test Retrieval

- **Method:**
  Obtain sample datasets for practical assessment.
- **Activities:**
  - Access data portals or request data from providers.
  - Perform test retrievals to evaluate data latency and accessibility.

Deliverables:

- **D3:** An evaluation report detailing the suitability of Level 1 satellite products, including recommendations for products to be integrated into MJOLNuR.

Task 4: Assess Level 2+ Products

Objective:
Evaluate Level 2+ satellite products for their utility in plume characterization and assess their scientific validity for detecting materials of interest.

Subtask 4.1: Product Selection

- **Method:**
  Identify Level 2+ products from the catalog that are relevant based on Task 2 findings.
- **Activities:**
  - Focus on products providing aerosol optical depth, cloud properties, hot spot detection, and other relevant geophysical quantities.

Subtask 4.2: Scientific Validation

- **Method:**
  Evaluate the scientific methods used to derive Level 2+ products and their applicability to detecting plume materials.
- **Activities:**
  - Review processing algorithms and validation studies.
  - Determine the accuracy and reliability of the products in the context of nuclear plume detection.

Subtask 4.3: Evaluation Against Criteria

- **Method:**
  Assess Level 2+ products using the same evaluation criteria as in Task 3.
- **Activities:**
  - Compare Level 2+ products to Level 1 counterparts to identify advantages or limitations.
  - Consider the potential to accelerate integration into MJOLNuR.

Deliverables:

- **D4:** An evaluation report detailing the suitability of Level 2+ satellite products, including scientifically justified connections to plume materials and recommendations for MJOLNuR integration.

Task 5: Assess Forecasting Products

Objective:
Evaluate forecasting models for their utility in predicting downwind plume rise height and general fallout dispersal, and assess their potential for modeling nuclear plume dispersion.

Subtask 5.1: Analysis of Plume Materials and Model Capabilities

- **Method:**
  Utilize findings from the literature review to correlate plume constituents with variables represented in existing forecasting models.
- **Activities:**
  - **Correlation of Plume Constituents with Model Variables/Layers:**
    - Identify the physical and chemical properties of nuclear plume materials from Task 2.
    - Determine if existing model variables or layers (e.g., aerosol optical depth, particulate matter concentrations, volcanic ash, smoke) can serve as analogs for nuclear plume constituents.
    - Evaluate the models' representation of key processes affecting plume dispersion, such as buoyancy-driven plume rise, gravitational settling, wet and dry deposition, and chemical transformations.

Subtask 5.2: Evaluation of Data Assimilation and Plume Initialization

- **Method:**
  Assess the flexibility of each model's data assimilation system to incorporate plume characteristics and the feasibility of manual plume initialization.
- **Activities:**
  - **Manual Insertion of Plume Characteristics:**
    - Determine whether the models allow for manual input of plume source parameters, such as emission rates, particle size distributions, thermal energy release, and release heights.
    - Evaluate the ease of modifying initial conditions to represent nuclear detonation events based on the unique characteristics identified in Task 2.
  - **Assimilation of Remote Sensing Data:**
    - Examine the capability of models to assimilate remote sensing observations (e.g., satellite-derived aerosol optical depth, plume height, thermal anomalies) to improve plume representation.
    - Assess the potential for near-real-time data assimilation to enhance operational forecasting and responsiveness.

Subtask 5.3: Evaluation of Model Performance Using Analog Events

- **Method:**
  Analyze the performance of selected forecasting models in simulating events analogous to nuclear detonations.
- **Activities:**
  - **Collect Model Data from Analog Events:**
    - Gather existing studies and datasets where the selected models have been applied to high-energy atmospheric events similar to nuclear detonations (e.g., volcanic eruptions, large-scale industrial explosions).
    - Analyze how the models simulated plume rise, dispersion patterns, and deposition processes in these events characterized by significant thermal anomalies and particulate emissions.
    - Evaluate the models' ability to handle extreme thermal buoyancy, rapid vertical transport, and other phenomena associated with nuclear plumes.
  - **Compare to Ground Truth:**
    - Utilize reanalysis datasets, such as ERA5, as ground truth to compare the models' historical outputs for analogous events.
    - Assess the accuracy of the models in predicting key parameters such as plume rise height, dispersion patterns, and particulate concentrations.

Subtask 5.4: Technical Requirements Analysis (Concurrent with Above Activities)

- **Method:**
  Determine the hardware and software requirements for operational deployment of the models within MJOLNuR.
- **Activities:**
  - **Hardware and Computational Needs:**
    - Assess the computational resources required, including processing power, memory, and storage, based on documented model runs for similar high-energy events.
    - Evaluate options for optimizing performance, such as using reduced-resolution configurations or leveraging high-performance computing resources if necessary.
  - **Software and Licensing Considerations:**
    - Identify any licensing requirements, costs, and accessibility issues associated with each model (e.g., open-source vs. proprietary software).
    - Evaluate the compatibility of model software with MJOLNuR's planned architecture, operating systems, and data formats.

Deliverables:

- **D5:** A comprehensive report that includes:
  - **Model Evaluations:**
    - Detailed assessments of each forecasting model's capabilities in simulating nuclear plume dispersion based on their documented performance in analogous events.

    - Comparison of models based on accuracy, flexibility, computational requirements, and potential for modeling nuclear plume scenarios.

Task 6: Assess the Feasibility of Developing an Operational Application

Objective:
Determine the feasibility of integrating the assessed products into a usable, operational application (MJOLNuR) and identify potential challenges.

Subtask 6.1: Feasibility Analysis

- **Method:**
  Synthesize findings from Tasks 1–5 to evaluate overall feasibility.
- **Activities:**
  - Assess alignment of available products with project goals.
  - Identify gaps or limitations in data or modeling capabilities.

Subtask 6.2: Integration Strategy Development

- **Method:**
  Outline a high-level architecture for MJOLNuR, detailing how selected products will be integrated.
- **Activities:**
  - Define data processing workflows, storage solutions, and user interface requirements.
  - Consider interoperability with DoD systems and compliance with data standards.

Subtask 6.3: Challenge Identification and Mitigation Planning

- **Method:**
  Identify potential software engineering and scientific challenges.
- **Activities:**
  - Evaluate risks related to data volume, computational load, and real-time processing.
  - Develop mitigation strategies and contingency plans.

Deliverables:

- **D6:** A comprehensive feasibility report outlining the proposed operational application, potential challenges, and strategies for Phase II development.

Task 7: Final Reporting and Deliverables Compilation

Subtask 7.1: Report Integration

- **Method:**
  Compile all deliverables into a cohesive final report.
- **Activities:**
  - Integrate findings from all tasks.
  - Ensure consistency, clarity, and completeness of documentation.

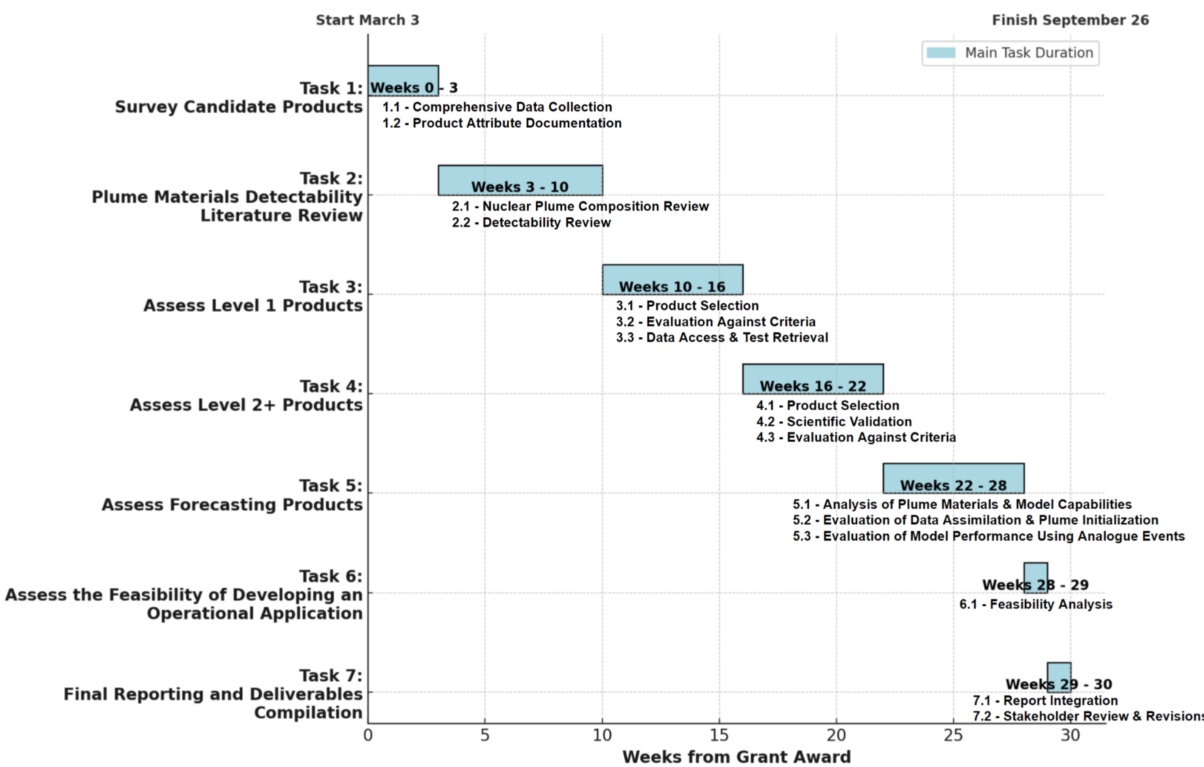
Subtask 7.2: Stakeholder Review and Revisions

- **Method:**
  Submit the draft report for internal and stakeholder review.
- **Activities:**
  - Address feedback and make necessary revisions.
  - Prepare the final version for submission.

Final Deliverable:

- **D7:** The final Phase I report, including all findings, analyses, and recommendations, providing a solid foundation for Phase II activities.

Schedule of Major Events



Work Conducted and Location

All work will be conducted by Aulendur's research and development team, headquartered in Omaha, Nebraska with remote collaboration as necessary. We will utilize our existing computational infrastructure and software tools for data analysis and modeling. Collaboration with subcontractors and research institutions, if any, will be conducted under established agreements, ensuring confidentiality and data security.

4. Related Work.

As a newly formed company, Aulendur's collective experience is represented through the work of its founders and key personnel.

Project 1: Development of the Unified Satellite Data Normalization Service (USDNS)

While at SAIC from January 2024 to August 2024, Jorden led the design and implementation of the Unified Satellite Data Normalization Service (USDNS) for the United States Air Force's 557th Weather Wing. Recognizing the limitations of the existing monolithic CDFSII system, he proposed and executed a complete redesign from first principles. The USDNS processes Level 1b radiance data from various meteorological satellites—including GOES, Meteosat, Himawari, JPSS, and DMSP—using a containerized Kubernetes application with a modular design that allows for scalable processing. This system enables easy addition of new satellite feeds, consolidates data processing tasks, and provides an API for customers to request specific data, dynamically producing and delivering the requested files. Completed significantly ahead of schedule, this project exceeded government expectations. It is directly relevant to our proposed effort, involving the integration and processing of multi-source satellite data—a core aspect of our project. Jorden's successful leadership in delivering USDNS demonstrates his capability to manage complex data processing systems, ensuring scalability, modularity, and ease of integration, which aligns with our objectives of incorporating diverse satellite products and ensuring compatibility with DoD data standards. This work was conducted for the United States Air Force, 557th Weather Wing, for Dr Jay Martinelli who can be contacted at jason.martinelli@us.af.mil.

Project 2: Operations Manager, Mobile Nuclear Laboratory Flight

From August 2012 to December 2018, while serving in the United States Air Force, Jorden was instrumental in operationalizing and conducting the testing and R&D necessary for deploying a nuclear beta-gamma detector for the Air Force Technical Applications Center's (AFTAC) unique mobile nuclear plume analysis laboratory. He conducted critical analyses of the North Korean nuclear detonations in 2016 and 2017, providing essential data to the Joint Chiefs of Staff. His work required an in-depth understanding of plume characteristics and the behavior of nuclear materials in the atmosphere. As an airborne Scientific Applications Specialist, Jorden learned to guide the WC-135 Constant Phoenix aircraft into nuclear plumes at various altitudes and under diverse meteorological conditions. Utilizing onboard detectors, he tracked and analyzed invisible plume materials, effectively "chasing" plumes to gather vital data. This hands-on experience with nuclear plume detection and real-time analysis is directly related to our proposed project, providing invaluable insights into the operational challenges and technical requirements of nuclear plume detection and analysis systems. Jorden's expertise in managing the deployment of nuclear detection assets and understanding plume dynamics offers significant value to the development of MJOLNuR. His direct experience with nuclear detection systems and operational logistics ensures that our project will address real-world challenges faced during nuclear events. This work was conducted for the United States Air Force, Air Force Technical Applications Center, under the supervision of Major Jason Cammarata, who can be reached at jason.cammarata.2@us.af.mil.

5. Relationship with Future Research or Research and Development.

Anticipated Results of the Proposed Approach

By the end of Phase I, we expect to have thoroughly evaluated and identified the optimal satellite products, atmospheric models—including both physics-based and AI/ML approaches—aerosol and particulate monitoring tools, and relevant non-satellite data sources. This comprehensive assessment will determine the most suitable components for detecting and characterizing nuclear plumes within the MJOLNuR system.

We'll also develop a clear framework to ensure that these selected data sources and models are formatted and standardized for seamless compatibility with Department of Defense (DoD) data standards. This includes aligning with Joint Enterprise Data Interoperability (JEDI), integrating with Joint Center for Satellite Data Assimilation (JCSDA) protocols, and adhering to the National Information Exchange Model (NIEM).

Additionally, we'll conduct a feasibility study outlining the requirements for developing prototype algorithms in Phase II. This study will cover what's needed in terms of computational resources, data inputs, validation methods, potential challenges, and strategies to overcome them.

Significance of Phase I Effort as a Foundation for Phase II

Phase I is crucial because it sets the stage for a successful Phase II. By rigorously evaluating and selecting the most effective data sources and models, we'll build a strong foundation for developing prototype algorithms and designing the MJOLNuR architecture in the next phase.

Early identification of challenges related to data integration, model compatibility, and algorithm development will allow us to proactively address them, reducing potential risks in Phase II. The insights gained will help us refine the system requirements and technical specifications, ensuring that our development efforts are focused, efficient, and aligned with DTRA's objectives.

Engaging with key stakeholders throughout Phase I will ensure that our proposed solutions meet user needs and comply with DoD standards, making it easier to adopt and integrate them in Phase II.

Applicable Clearances, Certifications, and Approvals for Phase II

To advance into Phase II testing and development, we recognize the need to secure appropriate clearances, certifications, and approvals. We will initiate the Facility Clearance (FCL) process suitable for the project's classification level, potentially establishing a cleared facility in Omaha, Nebraska, if collaboration at DTRA's Fort Belvoir facilities is not feasible. All current Aulendur employees hold active Top Secret/Sensitive Compartmented Information (TS/SCI) clearances, and any additional personnel will obtain the necessary clearances as a condition of employment. We will ensure compliance with the Department of Defense's Risk Management Framework (RMF) by obtaining an Authority to Operate (ATO) for MJOLNuR, implementing all required cybersecurity controls. Additionally, we will secure data use and sharing agreements for access to controlled or sensitive data sources and adhere strictly to International Traffic in Arms

Regulations (ITAR) and Export Administration Regulations (EAR) when handling export-controlled data or technology. This demonstrates our commitment to meeting all security and regulatory requirements essential for Phase II activities.

6. Commercialization Strategy.

Primary Commercialization Pathway: Contract with DTRA through SBIR Phase III

Our primary commercialization strategy for the MJOLNuR is to secure Phase III funding from DTRA following the successful completion of the SBIR phases I and II. Beyond DTRA, MJOLNuR holds significant potential for enhancing the capabilities of the Air Force Technical Applications Center (AFTAC) and the United States Atomic Energy Detection System (USAEDS). AFTAC, which operates the largest sensor network in the U.S. Air Force, plays a critical role in monitoring nuclear treaty compliance and detecting global nuclear events.

MJOLNuR addresses the exact needs identified by AFTAC in their **2024 BAA** (ID FA702224S0001) **Topic 005** such as, *"Advanced meteorological modeling tools and techniques, transport and dispersion modeling techniques, uncertainty estimation, and high performance computing."* and *"Meteorological model development, advanced weather data assimilation techniques, ensemble modeling and uncertainty estimation techniques, transport and dispersion modeling, and high-performance computational techniques."*. It also lays the groundwork for extending the capabilities to include other AFTAC objectives such as *automating seismic detection, LIDAR integration, and so on.* With over 3,600 sensors globally, USAEDS requires an advanced, scalable solution like MJOLNuR to meet its growing operational demands. AFTAC has the funding in place to support such projects, making this a prime market for immediate commercialization.

Private Sector Commercialization Opportunities

While MJOLNuR is primarily designed for government use, its advanced capabilities have significant potential in the private sector. The core architecture of MJOLNuR can be adapted to serve various industries by providing real-time atmospheric monitoring and predictive analytics.

- **Commercial Aviation Safety**: MJOLNuR's ability to detect and forecast the dispersion of aerosols and particulates can be leveraged by airlines and air traffic controllers to enhance flight safety. By monitoring volcanic ash clouds, wildfire smoke, or aerosols from industrial incidents, MJOLNuR can help reroute flights to avoid hazardous airspace, protecting aircraft engines and ensuring passenger safety.
- **Risk Assessment and Insurance**: Insurance companies can employ MJOLNuR for predicting and managing environmental risks associated with nuclear or industrial incidents. By providing detailed forecasts of hazard dispersion, insurers can better assess risk exposure, adjust premiums, and expedite claims processing in the aftermath of environmental disasters.
- **Industrial Safety and Compliance**: Industries such as oil and gas, chemical manufacturing, and power generation can use MJOLNuR to monitor emissions and detect accidental releases of hazardous materials. This aids in ensuring compliance with environmental regulations and enhances emergency response capabilities.

Market Need and Size

- **DoD and Federal Market:** AFTAC has a long-standing mission to monitor nuclear treaty compliance through its operation of the United States Atomic Energy Detection System (USAEDS). In recent years, AFTAC has demonstrated a clear commitment to funding projects that improve nuclear detection technologies, having issued several Broad Agency Announcements (BAAs) specifically seeking innovative solutions for enhancing the capabilities of USAEDS. The current **AFTAC BAA 2024** (ID FA702224S0001) explicitly calls for advanced technologies to support nuclear treaty monitoring, atmospheric and space detection, and enterprise-wide modernization.
- **Private Sector Market:** The environmental monitoring market is valued at billions of dollars globally, with growing demand for real-time data and predictive models for disaster preparedness. The oil and gas industry and the insurance sector are potential markets for customized applications of MJOLNuR, though these are secondary to its core government use case.

Phase/Year	**Description**	**Quantitative Goals**
Phase I (Year 1)	Complete the feasibility study, evaluate data sources, and establish relationships with DTRA, AFTAC, and other DoD agencies.	Establish potential contract discussions and partnerships with DTRA and AFTAC. Initial funding of $500K - $1 million.
Phase II (Years 1-3)	Develop and test MJOLNuR prototypes. Expand discussions with USSTRATCOM, USNORTHCOM, and other government customers.	Achieve $2 million in development funding for prototype testing and early-stage deployment
Phase III (Years 3-4)	Secure an acquisition contract with DTRA for full-scale deployment of MJOLNuR. Pursue additional contracts with AFTAC and other DoD agencies.	Achieve $10 million in revenue through Phase III contracts with DTRA and other DoD agencies.
Post-Phase III (Years 4-5)	Broaden MJOLNuR deployment within other DoD agencies. Explore private sector opportunities for environmental monitoring and risk assessment.	Secure a full contract with AFTAC, valued at $5 million annually. Expand revenue to $15-20 million through additional DoD contracts and niche private sector applications.

7. Key Personnel.

Jorden Gershenson - *Principal Investigator***:**

University of Nebraska Omaha - **MS, Computer Science w/ AI Concentration** *(Ongoing)*
University of Arkansas Grantham - **MS, IT Project Management** *(2023)*
Columbia College - **BA, Business/Computer Information Systems** *(2019)*
Community College of the Air Force - **AAS, Scientific Analysis Technology** *(2015)*

Relevant Experience

Jorden brings a robust technical background and extensive experience in leading complex initiatives within government and defense sectors, with significant contributions to nuclear detection and analysis, as well as advanced data processing systems.

While serving in the United States Air Force, Jorden was instrumental in operationalizing and conducting the testing and R&D necessary for deploying a nuclear beta-gamma detector for the Air Force Technical Applications Center's (AFTAC) unique mobile nuclear plume analysis laboratory. He conducted critical analyses of the North Korean nuclear detonations in 2016 and 2017, providing essential data to the Joint Chiefs of Staff. His work required an in-depth understanding of plume characteristics and the behavior of nuclear materials in the atmosphere. As an airborne Scientific Applications Specialist, Jorden learned to guide the WC-135 Constant Phoenix aircraft into nuclear plumes at various altitudes and under diverse meteorological conditions. Utilizing onboard detectors, he tracked and analyzed invisible plume materials, effectively "chasing" plumes to gather vital data. This hands-on experience with nuclear plume detection and real-time analysis is directly relevant to MJOLNuR, offering invaluable insights into the operational challenges and technical requirements of such a system.

Following his military service, Jorden became a Program Manager and Technical Lead at SAIC, where he spearheaded the development of satellite-based cloud analysis and modeling applications for the Air Force Weather Agency. One of his notable achievements at SAIC was leading the Unified Satellite Data Normalization Service (USDNS) project. Jorden modernized and scaled the ingestion and processing of satellite data for the 557th Weather Wing by integrating multiple satellite feeds and implementing data normalization techniques. The modular design he developed allowed for easy scalability—key components that align with MJOLNuR's proposed architecture. His successful leadership in delivering USDNS demonstrates his capability to manage complex data processing systems that are scalable, modular, and easily integrable.

Jorden's combined expertise in nuclear plume analysis, advanced data processing, and AI/ML technologies positions him as a vital contributor to MJOLNuR. His direct experience with nuclear detection systems and operational logistics, coupled with his technical leadership, ensures that the project will be executed with precision and in alignment with DTRA's mission to enhance national security.

Aaron Parker - *Assisting Investigator:*

Michigan State University - **MS, Management, Strategy, and Leadership** *(2020)*
Columbia College - **BA, International Business Administration** *(2016)*

Relevant Experience

Aaron Parker brings a unique blend of technical expertise and strategic leadership from his extensive experience within the U.S. Air Force, particularly his role as the Superintendent for Wargame Analysis at the Air Force Wargaming Institute. Aaron has led advanced wargaming exercises that integrate cutting-edge technologies to deliver strategic insights to Air Force senior leadership. His work focuses on delivering actionable intelligence that shapes operational strategies—a key asset in the development and deployment of the MJOLNuR. In addition to his leadership in wargaming, Aaron's tenure at the Air Education and Training Command (AETC) Headquarters provided him with direct experience working alongside MAJCOM commanders to guide strategic vision and operational implementation. His ability to navigate complex government structures and processes will be critical in ensuring MJOLNuR's success, particularly as the system integrates into Department of Defense (DoD) platforms.

8. Foreign Citizens.

N/A

9. Facilities/Equipment.

All Phase I activities will be conducted at Aulendur's headquarters in Omaha, Nebraska, utilizing our existing facilities and resources. While our team is equipped with personal workstations, the scope of this project requires handling large volumes of satellite data and conducting extensive comparisons of forecasting model outputs and data assimilation processes. To meet these computational demands, we will acquire a dedicated server, as detailed in the proposal budget. This server will significantly enhance our data processing capabilities, ensuring efficient and effective analysis crucial for the project's success.

Our facilities comply with all federal, state of Nebraska, and local environmental laws and regulations. Since the work involves computational analysis without any physical manufacturing or laboratory experiments, there are no concerns related to airborne emissions, waterborne effluents, external radiation levels, outdoor noise, solid and bulk waste disposal, or the handling and storage of toxic and hazardous materials.

10. Subcontractors/Consultants.

NA

11. Prior, Current or Pending Support of Similar Proposals or Awards.

No prior, current, or pending support has been provided for proposed work.

12. Technical Data Rights.

None

13. Identification and Assertion of Restrictions on the Government's Use, Release, or Disclosure of Technical Data or Computer Software

The Offeror asserts for itself, or the persons identified below, that the Government's rights to use, release, or disclose the following technical data or computer software should be restricted:

Technical Data or Computer Software to be Furnished with Restrictions	Basis for Assertion	Asserted Rights Category	Name of Person or Organization Asserting Restrictions
None	N/A	N/A	Aulendur LLC