IARPA's Space debris Identification and Tracking (SINTRA) Program

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1. Overview

Orbital debris is defined as any human-made space object orbiting Earth that no longer serves any useful purpose [1]. Orbital debris poses a risk to all space missions, including those of the Intelligence Community (IC). With an average low Earth orbit (LEO) impact velocity of 22,500 MPH, even the smallest of debris can cause significant damage, as demonstrated by the 3.8 mm diameter pit produced by the impact of a 0.2 mm paint chip on STS-71 [2]. Currently, there are over 100 million objects greater than 1 mm orbiting the Earth,[3, 4] however, it is estimated that less than 1 percent of debris that can cause mission-ending damage are currently tracked [5]. Moreover, due to the dynamic and variable nature of the near-Earth space environment, predicting the trajectory of the debris is extremely difficult and necessitates persistent monitoring [6]. While debris larger than 10 cm are currently detected and tracked, present capabilities are inadequate for smaller debris [7]. Debris that is too small to track, often termed "lethal non-trackable debris" (LNT), [8] can create significant damage to spacecraft and even jeopardize space missions. The detection, tracking, and characterization of LNT debris would support safer operation of valuable space assets worldwide [9].

The Intelligence Advanced Research Projects Activity (IARPA) — the advanced research and development arm of the Office of the Director of National Intelligence —launched a program that aims to revolutionize our nation's ability to detect, track, and characterize miniature orbital space debris.

The Space debris Identification and Tracking (SINTRA) program represents the Intelligence Community's first effort to track small space debris. The program's resulting technologies hold the potential to protect manned spacecraft and other valuable space assets from significantly damaging threats, enabling safer space operations for all countries and industries using Earth's orbit.

IARPA awarded SINTRA research contracts to the following four prime contractors, which together with sub-contractors bring a group of 12 academic and private-sector organizations into the program:

- Advanced Space, LLC
  - ExoAnalytic Solutions
  - Orion Space Solutions
- BlueHalo
  - University of Alaska Fairbanks
  - University of Michigan
- SRI International
  - Leidos
  - SCOUT Space Inc.
- West Virginia University Research Corporation
  - InTrack Radar Technologies
  - Stratagem Group

The SINTRA program was launched in June 2023 and includes within its test and evaluation team MIT Lincoln Laboratory, Naval Research Laboratory, Los Alamos National Laboratory, and Johns Hopkins University Applied Physics Laboratory.

SINTRA is developing innovative technologies to: (a) improve orbital debris detection and tracking; (b) reduce uncertainties of debris data in orbit propagation and prediction; and (c) characterize orbital debris size, density, and mass.

SINTRA pursues a novel and additive multi-phenomenology approach to push the detection boundaries of existing sensors, including real and simulated sensor data analysis for comprehensively studying sensor performance vis-à-vis the program metrics. A primary aim of SINTRA is to leverage previously overlooked debris signatures in existing data collections and define an architecture that can foster and exploit new sensor systems as they become available. Through the solutions proposed by the selected teams, SINTRA is investigating unique and integrated data analysis methods consisting in combinations of ground-based sensor data (radar, optical, etc.) with concurrent observations of existing plasma and radio occultation observations from on-orbit satellites. SINTRA will detect debris through the combination of traditional backscatter radar techniques with the analysis of the plasma signatures that result from modeling debris traveling through the ionosphere. The effort offers resilience and flexibility because multiple types of plasma wave disturbances will be investigated. Further, SINTRA is also developing next-generation probabilistic models for upper atmosphere density, the largest source of uncertainty in orbital drag prediction modeling at LEO.

The selected teams are applying novel Artificial Intelligence / Machine Learning (AI/ML) techniques to analyze current data and predict future performance of existing Modeling, Analysis, and Simulation (MA&S) capabilities. It is anticipated that AI/ML methods applied to optical and radar data will decrease the minimum Signal-to-Noise-Ratio (SNR) required for debris detection. The SINTRA teams will leverage data from the existing sensor networks and test the implementation of advanced AI/ML processing techniques that have been shown to outperform state-of-the-art convolutional and recurrent Neural Networks (NNs).

2. Program Background

SINTRA addresses the limitations in current assessments of the orbital debris population. NASA estimates that there are over 100 million particles greater than 1 mm orbiting the Earth [10]. However, estimates for small debris are largely based on collisional detections during the US space shuttle mission, which has now been retired [10]. These collisional detections were restricted to measuring debris strikes at altitudes below 600 km, the upper limit of space shuttle operations, and were then used to estimate the small debris population at a specific range of altitudes [11].

While ground-based sensors continue to improve their detection capabilities, the ground sensor detection sensitivity rapidly decreases with increasing altitude and is limited to observing high latitudes. The ground sensors in the United States Space Surveillance Network (SSN) can detect 10 cm objects at 2,000 km altitude in LEO and 1 m objects at 35,786 km altitude in GEO. Unfortunately, ground-based sensors are not able to track small objects due to the debris' relatively high angular velocity and their need for remaining in staring mode to count the number of objects passing through their small fields of view. The largest source of uncertainty exists in the ability to interpret the signal strength to determine the size or mass of the object passing through the field of view [7].

The orbital debris models developed at NASA are based on either impact data from on-orbit experiments or remote detection using a variety of optical telescopes and radar systems, as illustrated in Fig. 1. There is, however, a gap between these measurement types that has yet to be constrained by actual data, a problem that SINTRA hopes to solve. Much of the contributions for radar measurements are the Haystack Ultrawideband Satellite Imaging Radar (HUSIR) and the Haystack Auxiliary radar (HAX) systems operated by MIT Lincoln Laboratory. Additional information regarding contributing sensors can be found on the NASA Orbital Debris Program Office website [12].

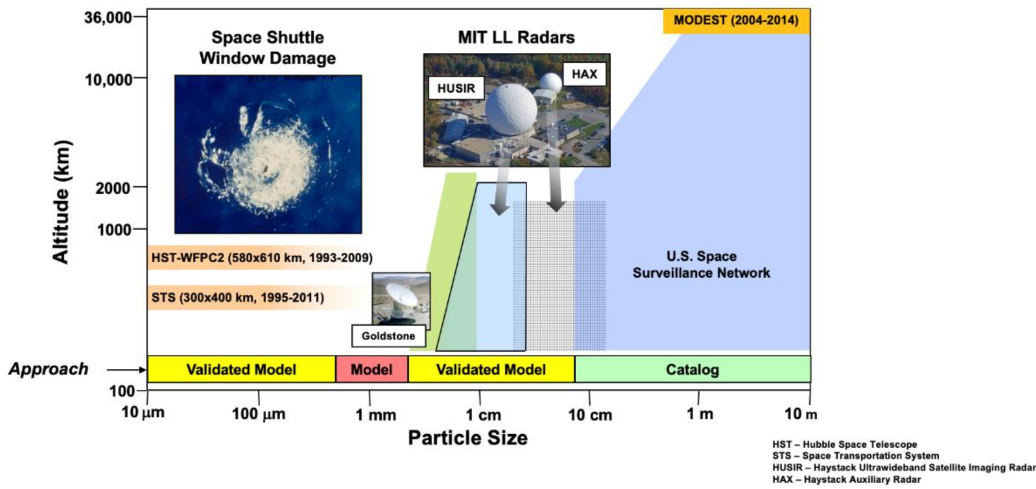

Fig. 1: Measurement data used by the NASA Orbital Debris Program Office to describe orbital debris about Earth. Figure from NASA/ODPO [12].

Most of the small orbital debris population resides in high LEO, with a mean altitude of 850 km [3]. However, due to the diminished atmospheric drag at high altitudes, more orbital debris is created than removed. This makes current orbit characterization for small debris even more uncertain [5].

An estimate from the SSN for the number of debris particles greater than 10 cm is displayed in Fig. 2, published by the NASA Orbital Debris Program office. Prior to 2010, two events are responsible for adding 40% to the LEO debris estimates [13]: the Chinese Anti-satellite Test (ASAT) in 2007 [14] and the collision of the Cosmos-Iridium satellites in 2009 [15]. These two events significantly increased the challenges of safely operating assets in LEO. More recently, the ASAT test conducted by the Russian Federation in November 2021 has caused a substantial increase in catalogued debris [16].

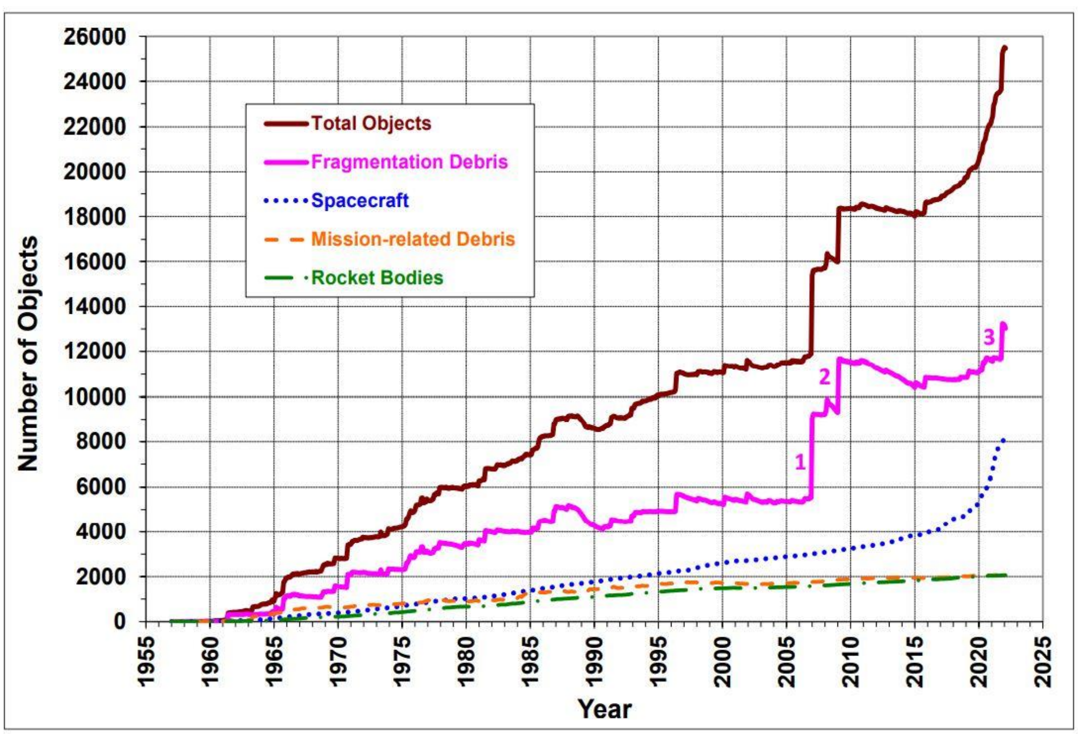

Fig. 2: Space Surveillance Network estimate of the number of objects greater than 10 cm as a function of time,

based on data available on 1 March 2022. The three annotated increases debris correspond to (1) the Chinese ASAT test conducted in 2007, (2) the accidental collision between Iridium 33 and Cosmos 2251 in 2009, and (3) the Russian ASAT test conducted in November 2021. Image from NASA/ODPO [12].

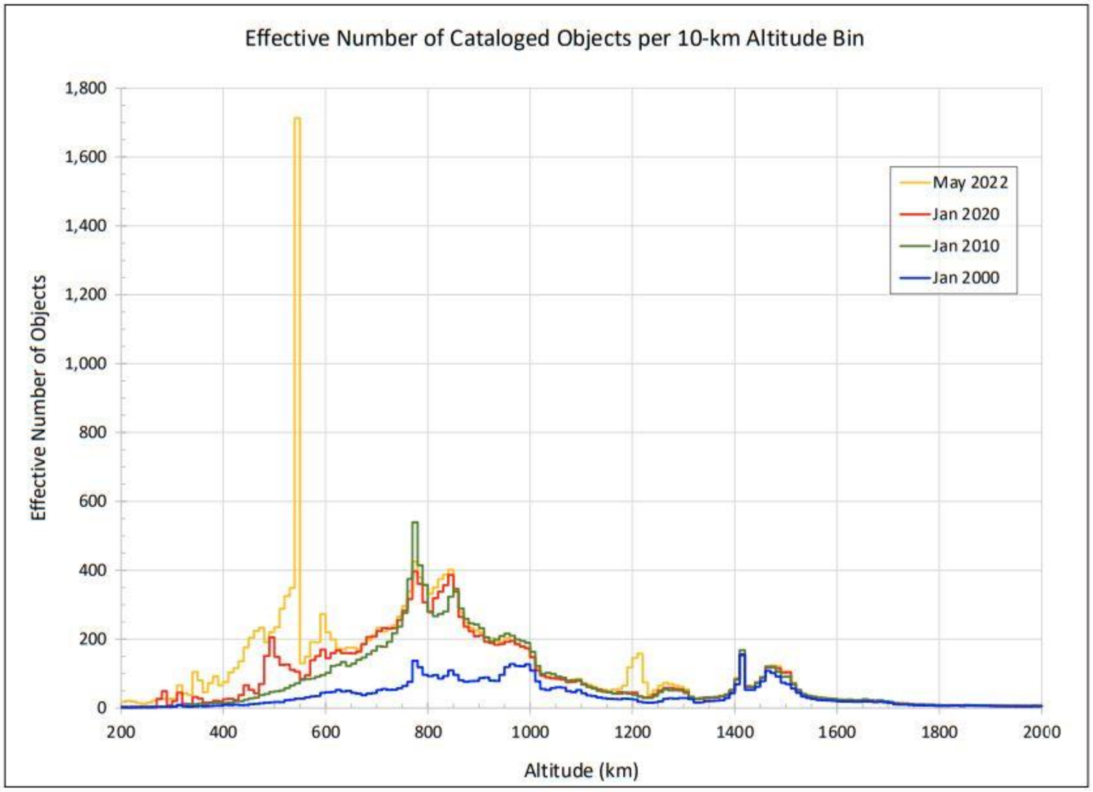

Fig. 3: Space Surveillance Network estimate of the number of objects greater than 10 cm as a function of altitude. Image from NASA/ODPO [17].

Fig. 3 shows the increase in catalogued objects as a function of altitude, also published by the NASA Orbital Debris Program Office. Again, the Cosmos-Iridium collision and Chinese ASAT test debris fragments dominate the increase in objects from 2000 to 2010. The increase objects from 2010 to 2020 is due to the initial build-up of the Starlink large constellation and by the proliferation of CubeSats below about 650 km altitude. The increase from 2020 to 2022 is due to the Russian ASAT test, and also continues to be driven by proliferation of large constellations by commercial and government entities [17].

With the increase in the number of satellites launched over time, there is potential for rapid growth of the debris population. Therefore, active means are necessary for quickly characterizing the dynamic orbital debris environment, allowing for the ability to prevent satellite damage through orbit selection, and collision mitigation and remediation. A non-collisional capability to detect small debris from the ground, and in situ with existing sensor technology, would provide the most immediate contribution for understanding the small debris population.

Recent work has demonstrated that orbital debris becomes charged due to its interaction with the background plasma, causing perturbations in the ion density [18]. It is theorized that the debris creates solitary waves, or solitons, in the surrounding ion density [19], and this phenomenon has been simulated computationally and demonstrated in laboratory environments [19, 20]. Ion density irregularities are frequently studied using ionosphere measurement systems, to include ground, air, space-based radar [21], ionosondes [22], Langmuir probes [23], and HF communication sensors [24]. As a result, since solitons are regularly detected in other naturally occurring plasma environments [25], there is reason to believe that debris-induced solitons offer opportunities for detection and tracking.

The successful completion of the SINTRA program would provide the world with the first collision-free detection method for small orbital debris, supporting the safe operation of valuable space assets.

A robust data collection effort is being executed as part of the SINTRA program to assemble diverse debris datasets for use in Research and Development (R&D) for algorithm training, and in Test and Evaluation (T&E) for comparing the algorithm performance against ground truth. As described in Section 5.1 (Development Data) , the T&E Team is conducting dataset development activities throughout the life of the program. A portion of these data are being made available to Performers for R&D. In addition, Performers have the ability to conduct their own supplemental dataset collections. At the conclusion of each program phase, Performers will make all datasets used for system development available to the T&E Team for the purpose of distribution to other Performers. The sharing of datasets across Performers ensures that improvement in performance is attributable to a team's superior technical approach rather than a greater accrual of development data resources. Public release of proprietary datasets is not a requirement; however, release for use within the SINTRA program is required. Additional details on program data can be found in section Program Data below.

3. Technical Challenges and Objectives

SINTRA teams are addressing two task areas (TAs) to meet the goal of SINTRA to exploit data for the detection, tracking, and characterization of space debris 0.1 – 10 cm in size. The threshold at which to track debris clouds instead of individual debris objects will be determined by the Performer teams. SINTRA teams are pursuing novel approaches to each of these TAs, and are required to create an end-to-end technology that incorporates software components from each TA.

Debris Detection, Tracking, and Characterization (TA1): The goal of TA1 is to research and develop novel, innovative techniques to detect, track, and characterize the size, mass, and density of space debris 0.1 – 10 cm in size, traveling in any orbital plane around the Earth.

During Task Area 1.A (TA1.A), the Performers debris detections are assessed against known tracked debris objects 10 – 40 cm in size in Low Earth Orbit (LEO), with orbital trajectories on publicly accessible databases (e.g., space-track.org).

During Task Area 1.B (TA1.B), the program metrics extend to debris 0.1 – 40 cm in size, from LEO to Geosynchronous Orbit (GEO). Teams will develop novel, explainable, techniques to establish accurate detection, tracking, and characterization of currently untracked debris and/or debris clouds to address this goal. It is assumed that there is an increased number of smaller debris traveling with the larger tracked debris, due to the power law size distribution. It is also assumed that larger debris can collide and create smaller debris objects. Additionally, smaller debris can travel independently of larger debris objects. Since debris less than 10 cm in size is not currently tracked and characterized with existing capabilities, Performers will develop methods to evaluate this approach that are potentially generalizable to other Performer approaches. T&E Teams will finalize protocol for evaluating explanations in Phase 1 and implement this protocol in evaluations during subsequent phases.

Persistent Monitoring of the Debris Population (TA2): The goal of TA2 is to demonstrate the capability to persistently monitor the orbital debris population for objects 0.1 – 10 cm in size. The TA2 deliverable must incorporate the variations in orbital trajectory due to gravitational perturbations from the Sun and Moon, and non-gravitational forces, including solar radiation and atmospheric drag.

Similar to TA1, the Performer will be assessed against known tracked debris objects 10 – 40 cm in size in LEO during Task Area 2.A (TA2.A), and debris 0.1 – 40 cm in size from LEO – GEO during Task Area 2.B (TA2.B).

4. Program Phases

The SINTRA program is anticipated to be a 4-year (48 month) effort, comprised of two (2) Phases. Each Phase will be 24 months in duration. Phase 1 will encompass Task Area 1, and Phase 2 will encompass Task Area 2, as described above.

SINTRA aims to develop new techniques to detect, track, and characterize debris and debris clouds of varying physical characteristics that influence the risk assessment decisions for potential impact damage, including debris size, shape, density, and orbital regime. Program phases are designed to test Performer systems against increasingly challenging risk scenarios.

Within each program phase, there are three evaluation milestones at which Performers submit software deliverables to the T&E team for evaluation against sequestered datasets. The Phase 1 milestones are: (1) debris signature detection; (2) debris tracking; and (3) debris characterization. The Phase 2 milestones are: (1) debris detection time; (2) detection rate; and (3) revisit rate. Additionally, regression testing will be conducted during Phase 2 to ensure that the Phase 1 performance of Performer software deliverables is maintained during Phase 2 development.

Each evaluation is performed on sequestered datasets using Performer-submitted containerized software components. Aspects of evaluation that involve human adjudication or feedback will be performed by the T&E Team.

IARPA is providing development datasets and an evaluation harness developed by the T&E team. The same harness is for testing and evaluation of Performer-submitted software components at each subsequent evaluation milestone. The purpose of the evaluation harness is to enable Performer-site training, testing, and competition between debris algorithm developers. IARPA is also furnishing to Performers documentation of the program Application Programming Interface (API) developed by the SINTRA T&E Team. This Government Furnished Information (GFI) will facilitate productive and useful research in a consistent and standardized manner. The first version of the SINTRA API was provided to the Performers at the Kick-off Meeting and will be updated periodically thereafter.

Datasets developed by the T&E Team for each program phase is partitioned into development and evaluation datasets. In addition to the T&E development data, Performers are expected to create their own development datasets aggregated from open source or self-generated using creative techniques and heuristics to infer debris population distributions. These datasets must be submitted to the T&E Team at the conclusion of each phase. The T&E team will combine all Performer datasets into a single dataset, such that it is releasable to all Performers as discussed in the Government Research section.

In addition to the development datasets and evaluation harness provided by the T&E team, IARPA is also furnishing to Performers the use of the Naval Research Laboratory (NRL) Space Physics Simulation Chamber (SPSC). Scaled near-Earth space-like plasmas are created in the SPSC's 5-m long by 1.8-m diameter main chamber and 2-m long by 0.55-m diameter source chamber. Independently controllable electromagnets allow for control of the shape of the axial magnetic field. As requested, each Performer has the opportunity to conduct two separate two-week experiments per Program Phase. An overview of the NRL SPSC facility was provided at the SINTRA Program Kick-off and Performers are coordinating the scheduling of experiments with NRL.

Additional GFI provided by IARPA to SINTRA Performers includes several weeks of curated high-resolution ionospheric measurements made over the southern portion of the Mountain Time Zone and one year of lower resolution ionospheric measurements made along the East Coast of the Continental United States during the IARPA HFGeo Program. The HFGeo data is included in the development datasets provided by the T&E team.

5. Program Data

The SINTRA dataset contain data from multiple ground and space-based sensor types, sensor locations, data formats, and data fidelity. These sensor types include but are not limited to optical, radar, plasma, and GNSS sensors. To ensure sufficient data are provided for system development and statistically reliable evaluations, the program T&E Team is implementing a robust and explicit data collection workflow.

The program includes two types of data – Development Data and Evaluation Data. Development data is utilized by Performers, as they see fit, to conduct research, development, error analysis, and algorithm training. Evaluation data is explicitly excluded from any algorithm training approaches and will be used by the T&E Team for performance evaluations of subcomponents, modules, and systems measured against the SINTRA program metrics.

5.1 Development Data

Development data is utilized by Performers, as they see fit, to conduct internal research, development, error analysis, and algorithm training. Each Performer possesses a unique technical solution to the SINTRA challenge, and accordingly requires different development data depending on their approach.
There are three types of development data used in the SINTRA program, as illustrated in Fig. 4:

- **Government Research and Test Sets** – Datasets collected, annotated, and curated by the T&E Team. Most of these data is sequestered, but a small portion is provided to Performers for R&D (prior to evaluation) and error analysis (following evaluation).
- **Researcher Collections** – Datasets collected, annotated, and curated by Performers. These datasets are delivered with a minimum of Government Purpose Rights, in accordance with FAR 52.227-14.
- **External Data Sources** – Data obtained by Performers that are available from third parties or that have been collected by a Performer outside of SINTRA is delivered with sufficient rights to allow the United States Government (USG) and the T&E Team to share this data with all Performers for their use in connection with the SINTRA Program.

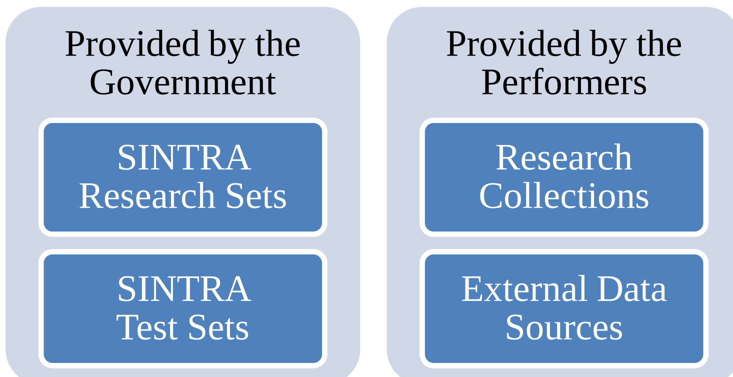

Fig. 4: Types of development data used in the SINTRA program.

5.2 Government Research and Test Sets

The T&E Team is developing SINTRA Research Sets (SRS) and SINTRA Test Sets (STS) throughout the program. The Government releases SRS to Performers to facilitate system development. STS are sequestered for the purpose of blind testing and evaluation, though small portions of this dataset may be released for the purpose of error analysis following official evaluation milestones. The volume of data in the STS is anticipated to be much larger than the SRS.

The SRS datasets includes new collections from the radar and optical systems currently used to develop debris models, as detailed in Fig. 1, to validate measurements by proposed systems. The new collections is dependent on Performer solutions and may be coordinated across multiple sensors to ensure maximum utility to the Performers. The SRS datasets also include collections of sensor data publicly accessible on the OpenMadrigal website. Led by the MIT Haystack Observatory since 1980, the OpenMadrigal project maintains and develops the Madrigal database, which is an open resource for geospace data. Madrigal is a robust, World Wide Web based system capable of managing and serving archival and real-time data, in a variety of formats, from a wide range of ground-based and some space-based instruments. An overview of Madrigal data can be found in material from the Boston University Incoherent Scatter Radar Summer School, publicly accessible at https://wikis.mit.edu/confluence/display/ASGScience/2022+ISR+School.

The T&E Team augments the data collected with auxiliary sensors not included in the Madrigal database. The T&E Team vets the quality of the auxiliary sensor data to verify contributions are appropriate to and not otherwise aberrant to Madrigal data. There is no overlap between known tracked debris objects in the SRS and STS datasets.

The T&E Team continuously develops SRS and STS database throughout the program, curating the database they develop to meet evaluation goals. The specifics of these collections are determined by the T&E Team throughout the program.

5.3 Researcher Collections

As indicated in the previous section, the IARPA is providing limited datasets (SRS) to Performers for system development. Each Performer is required to plan and carry out debris dataset development efforts. To minimize the risk of system biases, Performers must plan and implement steps to ensure that datasets include debris objects of varying size, shape, mass, density, and surface charge, and orbital regimes of varying altitude and inclination. Datasets assembled by Performers are referred to as SINTRA Researcher Collections (SRC). Performers are required to submit their most current SRC to the Government in a standard format at each evaluation milestone. Performers are permitted to withhold their internal SRC from other Performers until the end of each program milestone. At the conclusion of each milestone, the T&E Team will combine each Performer's SRC into a unified collection and will release this collection to all Performers. Sharing of the combined SRC helps ensure that improvement in performance on evaluation tasks is attributable to a team's superior technical approach rather than a greater accrual of development data resources.

All data collected, curated, annotated, synthesized, or generated by Performers created under the SINTRA program for R&D or any other purpose is provided to the Government as Deliverables. Software tools or algorithms created for the purpose of data annotation, synthesis, or generation under the SINTRA program for R&D purposes or otherwise is also provided to the Government as Deliverables with Government Purpose Rights in accordance with FAR 52.227-14, to allow use by the USG.

5.4 External Data Sources

Performers may utilize external datasets in addition to SRS and SRC datasets. External data are data obtained by Performers that are available from third parties or that have been collected by the Performer outside of the SINTRA program. An example of a third-party dataset would be sensor data from the amateur astronomy community or a university-sponsored space-based platform that has been approved by the dataset owner for release to the research community. Data collected by a Performer under a different program are considered external data, even if the other program's data collection was Government-sponsored.

5.5 Evaluation Data

SINTRA is utilizing distinct test data to evaluate Performer subcomponents, modules, and systems against program goals, objectives, and metrics. Each SINTRA Test Set (STS) consists of diverse debris object physical characteristics and orbital regimes. These data are constructed to evaluate program metrics in a balanced and intentional manner. The set of known tracked debris objects appearing in this collection does not overlap with that of the SRS dataset. This ensures that no known debris objects used for system development are included in the testing set, and that systems performance generalizes.

Intended uses of the STS evaluation datasets include both use by the T&E Team for independent evaluation of program Deliverables against target metrics and use by Performers to refine and improve their algorithms. Small portions of the evaluation datasets are provided to Performers to enable internal T&E and exploratory error analysis by Performers and to improve the consistency and communication between Performers and the T&E Team. Additional sequestered or external datasets may be used to supplement performance evaluations at the discretion of the SINTRA PM.

6. Test and Evaluation (T&E)

T&E is be conducted by an independent team of Government and contractor staff carrying out evaluation and analyses of Performer research Deliverables using program test datasets and protocols. The STS data and test protocols (in Evaluation Data) are the primary mechanism by which the T&E Team carries out their evaluations. The SINTRA Program is pursuing rigorous and comprehensive independent T&E to ensure that research outcomes are well characterized, deliverables are aligned with program objectives, and that algorithm performance is measured across the full range of conditions. Such T&E activities do not only inform IARPA and Government stakeholders on SINTRA research progress but also serve as invaluable feedback to the Performers to improve their research approaches, algorithm training practices, and system development. The SINTRA Program works closely with Government leaders in space situational awareness (SSA) and orbital debris to continually refine and improve T&E methodologies.

Performers have specific Deliverable Milestones at which all subcomponent and system algorithms and software is be delivered to IARPA and its designated T&E Team. The T&E Team then conducts evaluations at the direction of the SINTRA Program Manager (PM) and with the objective of characterizing the quality, functionality, and performance of the SINTRA Deliverables. In addition to quantitative measurements, T&E is carried out to establish a thorough understanding of the progress, status, and limitations of the Performer's research.

T&E results and feedback is provided to Performers at regular intervals to keep them abreast of current independent performance measurements and to inform and improve their R&D approaches and methods. T&E results from all Performers is shared with all teams to establish an understanding of the current state and progress of SINTRA research; T&E results is also be shared with USG external stakeholders, including their contractors, for Government purposes. For example, a Principal Investigator (PI) Review Meeting is held annually to share research ideas, progress, and results across the SINTRA program.

7. Program Metrics

Achievement of metrics is a performance indicator under IARPA research programs. IARPA has defined SINTRA program metrics to evaluate effectiveness of the proposed solutions in achieving the stated program goal and objectives, and to determine whether satisfactory progress is being made.

The final SINTRA T&E protocols and evaluation methodology were detailed at program Kick-off Meeting. Program metrics instead may be refined during the various phases of the SINTRA program; if metrics change, revised metrics will be communicated in a timely manner to Performers. The evaluation methodology may be revised by the Government at any time during the program lifecycle to better meet program needs.

SINTRA program target metrics were selected based on three factors:

- what is technically achievable but challenging based on current state-of-the-art in orbital debris detection, tracking, and characterization;
- what is statistically measurable based on the planned program evaluation data; and
- what is useful to mission partners based on USG stakeholder needs and use cases.

The following is a description of primary program metrics and target scores. Score targets increase for each successive program phase. Targets scores account for orbital regimes since the detection of debris size is a function of distance for existing capabilities.

A summary of metric targets by Phase is shown in Table 1; these metrics are subject to change over the course of the program. Accuracy targets are defined as aggregated statistical measures for a given phases' STS evaluation datasets, which contain a diverse set of debris physical characteristics and orbital regimes. These targets are estimates informed by current capabilities and use case requirements. To mitigate risk and better inform the Government regarding the appropriateness of phase-over-phase performance targets, the T&E Team will compare performance against baseline systems for each task approximating the current state-of-the-art. Further information about baseline models were furnished to Performers on June 29th at program Kick-off.

SINTRA Program Target Metrics and associated units are defined as follows:

- Debris detection (h): Time to detect new debris after a debris-generating event.
- Detection rate (%): Percentage of positive detections.
- Coverage (sr/km): The coverage metric is given in steradians per kilometer. A steradian (sr) is a solid angle unit. The surface area of a sphere is 4 pi steradians. Each orbital altitude, given in kilometers, can be represented by a sphere with a surface area of 4 pi steradians.
- Revisit rate (h): Time to revisit a previously detected debris object.
- False alarm rate (%): Percentage of false positive detections.
- Debris cloud: Multiple debris objects. Performers will determine the threshold at which to define and track debris clouds instead of individual debris objects.

- Space sensor size (cm^3): Maximum size for a new space-based sensor.
- Space sensor power (W): Maximum power for a new space-based sensor.

Table 1: SINTRA Program Target Metrics

	Phase 1				Phase 2			
	Task Area 1.A (TA1.A): Debris detection, tracking, and characterization		Task Area 1.B (TA1.B): Debris detection, tracking, and characterization		Task Area 2.A (TA2.A): Persistent debris population monitoring		Task Area 2.B (TA2.B): Persistent debris population monitoring	
	Range	+/-	Range	+/-	Range	+/-	Range	+/-
Debris diameter (cm)	10-40	0.25	0.1-40	0.05	10-40	0.25	0.1-40	0.05
Debris/cloud speed (km/s)	1.4-10.2	0.25	1.4-10.2	0.1	1.4-10.2	0.1	1.4-10.2	0.1
Debris/cloud position (km)	200-4,000	5 (LEO)	200-40,000	5 (LEO) 50 (GEO)	200-4,000	2 (LEO)	200-40,000	2 (LEO) 10 (GEO)
Debris particle density (kg/m^3)	0 - 22000	2000	0 - 22000	1000	0 - 22000	1000	0 - 22000	1000
Debris detection (h)	< 168	8	< 60	5	< 2	0.5	< 0.083	0.0167
Detection rate	> 70%	5%	> 80%	5%	> 80%	5%	> 95%	2%
False alarm rate	< 10%	2%	< 5%	1%	< 5%	1%	< 2%	0.5%
Coverage (sr/km)	> 1 pi	0.5 pi	> 2 pi	0.5 pi	> 3 pi	0.5 pi	> 4 pi	0.25 pi
Revisit rate (h)	< 168	8	< 48	5	< 2	0.5	< 0.083	0.0167
Space Sensor Size (cm^3)	N/A	N/A	< 700	50	N/A	N/A	< 500	50
Space Sensor Power (W)	N/A	N/A	< 150	10	N/A	N/A	< 50	5

8. Conclusion

IARPA established a 48-month multi-phase program for Space debris Identification and Tracking – SINTRA - to drive the state-of-the-art for exploitation of data capable of detecting orbital debris signatures, to demonstrate signature detection, and to foster the development of automated methods for signature analysis, debris tracking, and debris characterization. Under the program, four selected teams of Performer will pursue novel and additive multi-phenomenology approaches that will push the detection boundaries of existing sensors, including real and simulated sensor data analysis for comprehensively studying sensor performance vis-à-vis the program metrics.

The SINTRA program is pursuing rigorous and comprehensive independent T&E to ensure that research outcomes are well characterized, deliverables are aligned with program objectives, and algorithm performance is measured across the full range of data conditions. T&E activities not only inform Government stakeholders on SINTRA research progress but also serve as valuable feedback to the Performers to improve their research approaches, algorithm training practices, and system development. If successful, SINTRA will enable the first tracking capability for the small debris population, reducing risk to space operations, and transitioning new capabilities across multiple government organizations.

9. Technical References

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