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In response to National Oceanic and Atmospheric Administration (NOAA) Request for Information on Scope of Civil SSA Services[1]:

The University of Colorado (CU) Boulder, through a multidisciplinary collaboration between Ann and H.J. Smead Aerospace Engineering Sciences and Leeds School of Business, is targeting fundamental research in space sustainability focusing on areas such as technical capabilities for civil space traffic management, developing first principle based norms of behaviors, and methods for promoting a new generation of space entrepreneurs. The Space & Sustainability Initiative (SSI) at CU continues to support the Office of Space Commerce (OSC) in the charge put forth by Space Policy Directive-3 (SPD-3)[2] to provide basic SSA safety services to all space operators and making those basic services free of direct user fees while supporting new opportunities for U.S. commercial and nonprofit SSA services. SSI considers research institutions a notable part of achieving these goals. In the following paragraphs, CU Boulder addresses the scope of the civil SSA services under consideration by OSC.

Before addressing the candidate services for inclusion in OSC's TraCCS "free of fee" service, SSI would like to call attention to the statement that OSC suggests limiting participation in TraCCS to only satellite Owner/Operators (O/O) willing to accept the tenets of participation. TraCCS should endeavour to provide incentive for users to participate in the sharing of space safety information, however any withholding of basic SSA safety services may add unnecessary risk to the collective safety, stability, and sustainability of space. Instead, OSC may consider investigating research in areas of decision making[3], common pool resource management (socio-economic systems)[4], and cooperative game theory[5] in support of developing incentives that achieve participation. Additionally, TraCCS should consider the value of providing open access to TraCCS for research institutions and/or the public in addition to O/O in an effort to limit rent-seeking activities which ultimately inhibit innovation.[6]

The attached comments are submitted for discussion. The theme is promoting transparency, cooperation, and sharing in the name of space sustainability to maximize the economic value of the space domain. It is generally believed at SSI that providing public goods, such as data and technical services, to space operators allows for new entrants and encourages market growth (generating new value) while restricting services encourages rent-dissipation and market stagnation.

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https://www.colorado.edu/initiative/space-and-sustainability/

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Basic SSA Service Proposals and Comments

Proposal:
(1) Satellite Attributes, Capabilities, Status, and Point of Contact (Included). To maintain a database of primary (protected) assets, which contains basic satellite attributes (approximate dimensions, mass), indicates satellite trajectory change capabilities and current status, and includes 24/7/365 contact information to coordinate mitigation actions for conjunctions between active satellites.

> Agree. The above data should default to the public domain. An opt-out methodology on public sharing may be adopted to continue to protect intellectual property and national security as needed. The paradigm shift from opt-in to opt-out sharing is vital for promoting transparency and cooperation in the name of space sustainability.

Proposal:
(2) Receipt and Sharing of Predictions O/Os Ephemerides (Included). To receive predicted ephemerides from O/Os, store them in a manner that makes them available for download by other interested O/Os, and use them as the representation of the primary object for collision assessments (CA) screenings, risk assessment, and (when appropriate) mitigation planning.

> Agree. Predicted ephemerides should default to the public domain. An opt-out methodology on publicly sharing predicted ephemerides may be adopted as needed. Combined with (1), a paradigm of sharing this data would make new innovations in space weather prediction imminent.

Proposal:
(3) Routine Collision Assessment (CA) Screening and Conjunction Data Message (CDM) Production (Included). To screen primary objects against a robust satellite catalog, both routinely and on demand; and to generate CDMs for objects that violate the particular physical volumes used for the screening activity.

> Agree. The methodology used should strive to be open-source and on-demand, enabling validation and verification of new algorithms and methodologies.

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Proposal:
(4) Special CA Screening and CDM Production (Included). To perform an on-demand screening against a robust satellite catalog for a particular submitted ephemeris or set of ephemerides (usually for a confirmatory or speculative screening as part of maneuver planning).

> Agree. The methodology used should strive to be open-source and on-demand, enabling validation and verification of new algorithms and methodologies.

Proposal:
(5) Data Quality Evaluation (Included). To perform a first-order evaluation of the orbit determination and propagation of the (usually secondary but in principle both) objects' state estimates and co- variances in order to determine whether these inputs are of sufficient quality to serve as a basis for a durable risk assessment calculation

> Agree. The methodology used should strive to be open-source and on-demand, enabling validation and verification of new algorithms and methodologies.

Proposal:
(6) Launch Collision Avoidance (COLA) Screenings (Included). To perform timely screenings of a set of launch nominals against a robust satellite catalog in order to identify specific launch times during a launch window that would create unacceptably high collision risk and therefore should not be used.

> Agree. The methodology used should strive to be open-source and on-demand, enabling validation and verification of new algorithms and methodologies.

Proposal:
(7) O/O Ephemeris Generation and Curation with Covariance (Included). To use O/O telemetry and on-board global positioning system state information, as well as potentially other commercial tracking information, to generate a reliable predicted O/O ephemeris that includes covariance at each ephemeris point and incorporates planned maneuvers (and maneuver execution error).

> Agree. It is critical to assess the quality of all predicted ephemerides. TraCCS, with its unparalleled access to data measurements, will be uniquely positioned to validate the reliability of O/O ephemerides.

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Proposal:
(8) Re-entry Management and Assessment (Included). To perform re-entry forecasting and event pacing assistance for primary objects undergoing either natural decays or managed deorbits in order to assist the DoD in orchestrating the overall decay and decataloguing process.

> Agree. The methodology used should strive to be open-source and on-demand, enabling validation and verification of new algorithms and methodologies.

Proposal:
(9) Precision Probability of Collision Calculation (Included). To include in each generated CDM a Probability of Collision (PC) calculation that uses more advanced approaches for determining the appropriate hard-body radius (HBR) and employs a calculation technique appropriate to the particular dynamics of the encounter.

> Agree. It is vitally important to include metrics about system Type I and Type II errors when generating CDMs.[7] TraCCS, with its unparalleled access to data measurements and ephemerides, will be best suited to reporting on these metrics.

Proposal:
(10) Collision Consequence and Debris Production Potentials (Included). To calculate, using an appropriate model, an estimate of the number of trackable debris fragments that would be generated if a particular conjunction were to result in a collision.

> Agree. The methodology used should strive to be open-source and on-demand, enabling validation and verification of new algorithms and methodologies.

Proposal:
(11) Conjunction Object Solution Improvements with Additional Tracking (Included). To obtain additional tracking on the satellites involved in conjunctions of interest (typically the secondary objects), improve these objects' predicted states at the conjunction time of closest approach (TCA), and calculate higher-fidelity risk assessment metrics with this improved information.

> Agree. TraCCS should strive to make this service obsolete. While it is understood that current sensor networks are resource constrained, new innovations and policy can make this service no longer needed.

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Proposal:
(12) Expected Tracking Determination (Included). To generate a pass schedule and probabilities of detection for obtaining additional commercial tracking for conjunction-related objects, so that O/Os can infer the potential benefit of additional tracking and be able to schedule mitigation action decision points appropriately.

> Agree. This data should default to the public domain. An opt-out methodology on publicly sharing expected tracking determination may be adopted as needed.

Proposal:
(13) Risk Assessment Time History Plots (Included). To produce time-history plots of conjunction risk assessment parameters of interest to allow assessment of conjunction event phasing and stability.

> Agree. This data should default to the public domain. An opt-out methodology on publicly sharing conjunction events with particular assets may be adopted as needed.

Proposal:
(14) Space Weather Sensitivity (Included). To provide warnings about space weather perturbative events and to assess the effects the perturbation-induced atmospheric density uncertainty will have on conjunction risk assessment parameters.

> Agree. TraCCS should strive to make this service obsolete. The vast increase in spacecraft ephemerides combined with vehicle data will lead to innovations in space weather predictions that improve space safety, stability, and sustainability for all.

Proposal:
(15) Fusion of CA Products (Not Included). To combine CA products, such as CDMs or predicted ephemerides, from multiple providers into a single, higher-fidelity product that can then be used to enable CA risk assessment.

> Agree. TraCCS is a single SSA provider and should not be held accountable for validating and/or curating CA products from other providers. However, TraCCS may consider developing and/or adopting/promoting an open-source format for CA products that fosters data fusion among the industry.

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Proposal:
(16) PC Variability (Not Included). By considering bounding scale factors for the "true" size of the primary and secondary objects' covariances, to generate a matrix of possible PC values to allow risk assessors to assign a more conservative "high-water-mark" PC value.

> Disagree. PC variability falls under the same category as Conjunction Object Solution Improvements (11) and Space Weather Sensitivity (14). Services like these are required due to the highly uncertain nature of the space domain and providing such services brings attention to the technical and operational challenges. This service should be provided as a basic service while TraCCS fosters the developments and innovations that will make the service obsolete.

Proposal:
(17) Additional Concierge Services (Not Included). To provide on- call, personalized telephone support at all times by CA subject matter experts to assist O/Os with the interpretation of conjunction screening and risk assessment products.

> No comment.

Proposal:
(18) Anomaly Resolution (Not Included). To arrange for the obtaining and interpretation of anomaly resolution SSA products, such as point signatures (radar cross-section and/or photometry), time- series satellite signatures, and radar and optical imaging.

> Disagree. Understanding the nature of an anomaly in the space domain is critical to determine courses of action for all space operators in the orbital neighborhood. Determining if an unresponsive satellite is, for example, venting propellant allows other services to accurately assess the quality of future tracking updates, risk of breakups, and potential collision consequences.

Proposal:
(19) Design-time Assistance for Improved CA (Not Included). During the satellite construction and mission design phase, to assist O/Os in the prudent selection of mission orbits, satellite construction decisions to produce favorable light pollution properties, and the proper build-out of effective O/O ephemeris construction and CA software and procedures.

> No comment.

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Proposal:
(20) Maneuver Trade Space (Not Included). To assemble a visual aid that identifies particular maneuver times and intensities (and, for some maneuver types, durations) to achieve the desired level of conjunction risk reduction (for both the main conjunction and any other conjunctions that the particular maneuver might introduce).

No comment.

Proposal:
(21) Optimized Maneuver Recommendations (Not Included). In addition to the parameters in service (20) above, to include satellite contact restrictions, spacecraft maneuverability limitations, and O/O optimality preferences to construct a recommended maneuver plan to mitigate the main conjunction and ensure against the creation of any serious derivative conjunctions.

No comment.

Proposal:
(22) Breakup Detection, Tracking, and Cataloguing (Not Included). To commission routine surveillance tracking to detect satellite break- ups; and upon the detection of a break-up, to increase supplementary surveillance tracking to collect break-up uncorrelated tracks (UCT), perform UCT processing, obtain dedicated tracking on new candidate objects, and suggest/perform cataloging actions for stable candidates for which the country of origin can be established.

Disagree. Cataloguing is one of the primary functions of an SSA provider and is not only critical to space safety, stability, and sustainability, but is also critical to providing all of the other proposed services. Additionally, because the timeliness of determining that such an event has occurred is so critical to space safety, any SSA provider, TraCCS included, should prioritize owning this capability over relying on 3rd party services to alert the system of a potential breakup.

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Proposal:
(23) Maneuver Detection and Processing (Not Included). To commission heightened surveillance tracking on maneuverable objects; execute maneuver detection algorithms against the tracking obtained from such heightened surveillance; and for objects for which maneuvers are detected, perform appropriate maneuver processing to create a durable post-maneuver state estimate.

> Disagree. Maneuver detection is critical to maintaining custody of active space objects and is thus critical to providing all of the other proposed services. Any SSA provider should provide such a capability. Additionally, maneuver detection provides insight into space actor reliability and establishes trust between operators.

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