

AI-Enhanced Space Traffic Management and Space Domain Awareness

A software-centric architecture for tracklet extraction, multi-sensor fusion, and operational decision support using ground-based and space-based observations

Prepared by Indochina Space



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Executive Summary

The orbital environment is becoming more congested, and satellite operators now need faster, more reliable ways to detect, track, characterise, and assess objects in orbit. Space Traffic Management and Space Domain Awareness depend on converting raw observations from ground-based and space-based sensors into trusted operational intelligence.

Indochina Space and NurjanaTech provide a capability for this requirement. NurjanaTech supplies the core technology stack: AI-enhanced video analysis, automatic object tracking, tracklet extraction, multi-sensor fusion, digital twin simulation, and SPADAS operational decision support. Indochina Space acts as the systems integrator in Thailand, sourcing the required hardware, coordinating local deployment, integrating that hardware with NurjanaTech software, and managing customer-side implementation, training, and support.

The proposed architecture places a Video Analytics Measurement Layer between the sensor network and STM/SDA operations. This layer processes telescopic, electro-optical, infrared, radar, and future space-based observations to produce time-stamped detections, angular measurements, tracklets, fused observations, confidence-rated tracks, and orbit-update products. These outputs support conjunction assessment, debris monitoring, post-maneuvre confirmation, high-interest object tracking, sensor tasking, and operator decision support.

The system strengthens the observation-to-decision chain. Optical and infrared sensors provide angular measurements and object evidence. Radar can add range and range-rate data. Space-based sensors can provide observation geometries unavailable from the ground. NurjanaTech's tracking and fusion software combines these inputs into a more coherent operational picture, while SPADAS presents operators with threat assessment, alert management, manoeuvre support, visualisation, evidence replay, and audit-ready reporting.

AstroTwin provides a simulation and validation layer. It allows mission behaviour, optical tracking algorithms, sensor-tasking logic, and operator workflows to be tested before operational use. This reduces deployment risk and supports training, rehearsal, acceptance testing, and future system expansion.

The architecture is scalable and can support different levels of capability, from ground-based observation and AI-enhanced measurement generation to multi-sensor fusion, simulation, and future space-based observation.

This white paper proposes a practical route to improved STM and SDA capability: NurjanaTech provides the AI, tracking, fusion, simulation, and decision-support systems; Indochina Space provides the local systems integration, hardware sourcing, deployment management, and operational support needed to turn those systems into a working capability in Thailand.

Strategic Context: The Measurement Problem in STM and SDA

Space Traffic Management and Space Domain Awareness are often presented as catalogue, screening, and command-centre functions. In operational terms, they are first measurement functions. A system can only assess collision risk, identify abnormal behaviour, prioritise re-observation, or support operator judgement if it receives timely, calibrated, and orbit-relevant measurements.

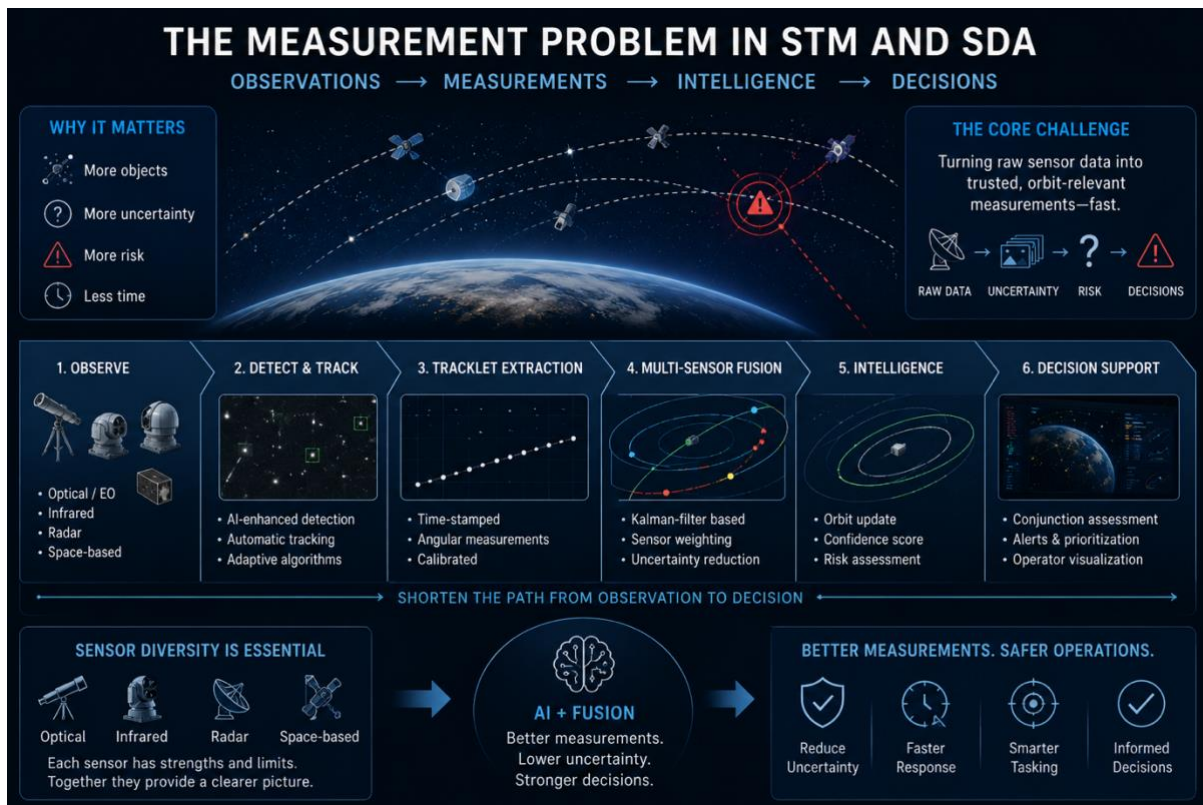


Figure 1: Measurement issues for space domain awareness.

The orbital environment is becoming more difficult to manage. More satellites are being launched into low Earth orbit, rideshare missions are releasing multiple objects in a single event, and debris populations continue to create uncertainty for operators. Many resident space objects are small, dim, poorly characterised, intermittently observable, or insufficiently tracked. A warning system that depends on stale or sparse catalogue data can therefore produce unstable risk assessments, missed follow-up opportunities, and compressed decision timelines.

The central challenge is the gap between observation and decision. Telescopes, electro-optical systems, infrared sensors, radars, and onboard cameras may all collect useful data, but raw imagery or sensor output does not automatically become operational intelligence. Each observation must be detected, associated with the correct object, time-stamped accurately, calibrated against the sensor geometry, converted into angular or positional measurements, and used to update an orbit estimate. If this chain is slow or unreliable, the operational value of the sensor network is reduced.

This matters most when uncertainty must be reduced quickly. A predicted conjunction may initially carry a large uncertainty volume. Fresh observations can stabilise the screening result, reduce false alarms, refine probability estimates, and indicate whether further observation, operator review, or manoeuvre planning is required. The same logic applies to debris monitoring, post-manoevrue confirmation, launch and early orbit support, and high-interest object tracking.

Operators therefore need measurement products rather than raw sensor files. The useful outputs are time-stamped detections, angular observations, tracklets, fused tracks, covariance estimates, confidence scores, and audit-ready evidence. A practical STM/SDA architecture must convert sensor data into these products consistently and fast enough to support operational decisions.

Single-sensor approaches are limited. Optical sensors can provide angular measurements and object evidence, but they are affected by weather, illumination, field of view, and atmospheric conditions. Infrared sensors can improve detection in selected conditions but still require calibration and correct interpretation. Radar can provide

range and range-rate information, but may have coverage, resolution, or bias constraints. Space-based sensors can observe geometries that ground systems cannot, but they introduce onboard processing, downlink, and mission-design constraints.

The requirement is therefore sensor diversity supported by fusion. Measurements from different sources must be combined intelligently, with degraded or biased sensors weighted appropriately and uncertainty carried through the process. This is what turns a collection of sensors into an operational SDA capability.

Artificial intelligence is useful because much of the measurement problem occurs before orbit determination. Space objects may appear as faint points, streaks, intermittent signatures, or low-contrast targets against star fields, cloud, sensor noise, and image artefacts. Detection and tracking logic must adapt to different sensors, exposure settings, angular rates, brightness levels, and observation geometries. AI-enhanced video analysis can help select suitable detection methods, maintain track continuity, reduce false detections, and support the generation of reliable tracklets.

For Thailand, this creates a practical systems-integration requirement. The capability is delivered by neither software nor hardware alone. Telescopes, electro-optical systems, infrared sensors, timing systems, computing infrastructure, communications links, and operator workstations must be sourced, installed, calibrated, and integrated with the software stack. Indochina Space provides this local integration function, while NurjanaTech provides the specialist tracking, fusion, simulation, and decision-support technologies.

The strategic requirement is clear: shorten the path from observation to decision. A credible STM/SDA system must turn sensor data into trusted measurement products, combine multiple sources, quantify uncertainty, and present operators with evidence they can use. The proposed Indochina Space and NurjanaTech architecture addresses this requirement by combining local hardware integration with AI-enhanced video analysis, tracklet extraction, multi-sensor fusion, simulation, and SPADAS operational decision support.

Indochina Space and NurjanaTech: Combined Capability

Indochina Space and NurjanaTech provide a combined STM/SDA capability with a clear division of responsibilities. NurjanaTech provides the specialist technology stack. Indochina Space provides the local systems-integration layer needed to deploy, operate, and support that technology in Thailand.

NurjanaTech's contribution is the software and algorithmic core of the capability. This includes AI-enhanced video analysis, automatic object detection and tracking, tracklet extraction, multi-sensor fusion, AstroTwin simulation and validation, and SPADAS operational decision support. Its systems address the early stages of the SDA chain as well as the operator-facing layer: detecting objects, tracking them, generating measurements, fusing data, assessing risk, and presenting decision-ready information.

Indochina Space's contribution is to turn that technology into a working local system. This includes identifying suitable telescopes, electro-optical sensors, infrared cameras, timing systems, computing hardware, communications links, storage, operator workstations, and related infrastructure. Indochina Space sources the required hardware, manages local contractors and installations, coordinates site preparation, supports calibration and acceptance testing, and integrates the hardware with NurjanaTech's software systems.

This integration role is essential because STM/SDA capability is not delivered by software alone. Sensors must be correctly selected, installed, timed, calibrated, connected, secured, and maintained. The resulting system must also fit the customer's operational environment, staffing model, reporting requirements, and future expansion plans. Indochina Space provides that local bridge between the customer, the physical infrastructure, and NurjanaTech's technology.

The main NurjanaTech building blocks are SPADAS, AstroTwin, NEOS, and associated AI tracking and fusion capabilities. SPADAS provides space safety and threat-management functions, including threat assessment, response recommendations, visual analytics, sensor integration, and ground-to-space communication. AstroTwin

provides digital twin simulation and validation for satellite behaviour, mission operations, and optical SSA/SDA scenarios. NEOS supports optical tracking and early orbit determination. The fusion and tracking capabilities support more complex sensor networks where optical, infrared, radar, and space-based observations must be combined into a coherent operational picture.

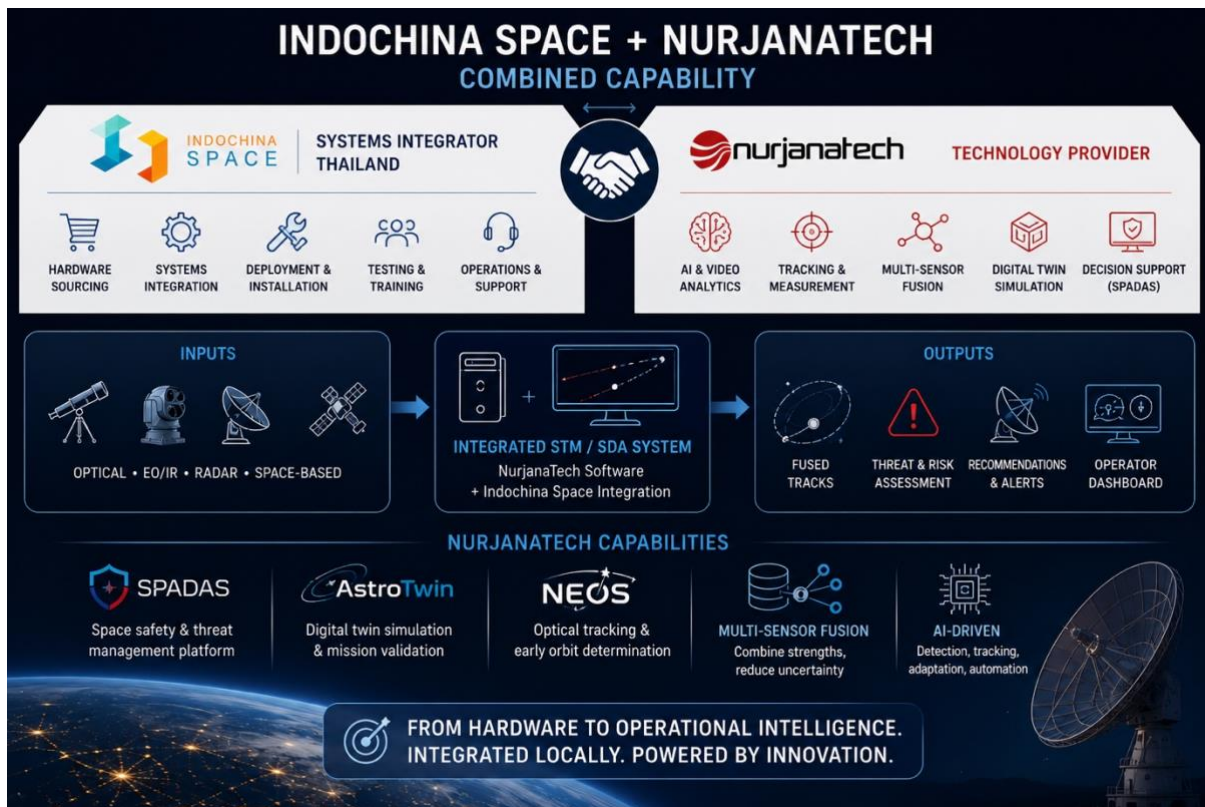


Figure 2: How NurjanaTech and Indochina Space work together.

The joint offer can be expressed simply:

NurjanaTech provides the STM/SDA technology stack. Indochina Space provides the local hardware, integration, deployment management, training, and operational support required to make that stack usable in Thailand.

This model gives customers a scalable route to capability. This model allows customers to adopt an architecture that can scale across sensor types, software functions, operational workflows, and future observation domains without exposing implementation sequencing or deployment assumptions.

The proposed operational architecture turns observation hardware into operational STM/SDA intelligence. It combines locally sourced and integrated hardware with NurjanaTech's software stack, allowing raw observations from ground-based and future space-based sensors to become validated measurement products, fused tracks, and operational decision support.

The architecture should be understood as a layered system rather than a single platform. Each layer performs a distinct function: sensors collect observations; AI-enhanced processing extracts detections and tracklets; fusion software combines measurements; orbit-determination tools refine object states; and SPADAS presents operators with risk, priority, and response information.

Architecture overview

The operational chain follows this sequence:

Sensors → AI video analytics → tracklet extraction → calibration → orbit update → multi-sensor fusion → confidence-rated track → SPADAS decision support

This structure supports multiple mission types: conjunction assessment, debris monitoring, launch and early orbit tracking, post-maneuvre confirmation, high-interest object monitoring, and future space-based SDA.

The Video Analytics Measurement Layer is positioned between imaging sensors and operational screening or decision tools. Its purpose is to convert optical and infrared video streams into time-stamped detections, tracklets, angular observations, and fused measurement products.

Sensor layer

The sensor layer includes the hardware used to observe resident space objects. Depending on customer requirements, budget, site conditions, and mission priorities, this may include:

- Optical telescopes for angular observations and object evidence.
- Electro-optical tracking systems for continuous target tracking.
- Infrared sensors for selected low-light, long-range, or difficult-visibility conditions.
- Radar inputs where range and range-rate data are available.
- Timing systems, calibration tools, edge-processing hardware, data links, storage, and operator workstations.
- Future space-based sensors, hosted payloads, or CubeSat-mounted observation systems.

Indochina Space identifies, sources, procures, installs, and integrates the required hardware in Thailand, then ensures that the physical system can interface with NurjanaTech's software stack. This includes practical issues such as site preparation, power, communications, timing integrity, camera calibration, sensor metadata, operator workstations, and maintenance arrangements.

Video Analytics Measurement Layer

The Video Analytics Measurement Layer is the first major software-processing stage. It receives image sequences, video streams, or sensor feeds and converts them into structured measurement products.

This layer performs several functions:

- It detects candidate objects in the image frame.
- It tracks detected objects across successive frames.
- It rejects obvious false detections and background artefacts.
- It associates frame-level detections into object tracklets.
- It records timing, sensor state, image quality, and calibration metadata.
- It produces angular observations suitable for orbit determination.

NurjanaTech's electro-optical tracking comprises systems in which image sensors, positioning systems, control systems, and video trackers operate together. The software processing layer uses machine learning to select appropriate detection and tracking algorithms and to reduce dependence on manual operator choices during dynamic tracking activity.

For STM and SDA, this is essential. Space objects may appear as faint points, short streaks, glints, intermittent detections, or low-contrast features against a star field. The processing layer must therefore adapt to target

brightness, angular rate, background noise, sensor type, exposure setting, atmospheric conditions, and observation geometry.

Tracklet and measurement generation

The primary output of the video analytics layer is the tracklet. A tracklet is a short sequence of time-stamped angular measurements associated with the same observed object. It is the bridge between raw imagery and orbit determination.

A useful tracklet product should include:

- Object or candidate identifier.
- Sensor identifier.
- Observation time stamps.
- Right ascension and declination, or equivalent angular coordinates.
- Estimated angular rate.
- Brightness or magnitude estimate where available.
- Measurement uncertainty.
- Calibration metadata.
- Detection confidence.
- Processing provenance.
- Quality flags.

The architecture should preserve the raw imagery and the derived measurement products. This allows operators and analysts to replay an event, inspect the evidence, validate the detection logic, and compare outputs against known catalogues or independent measurements.

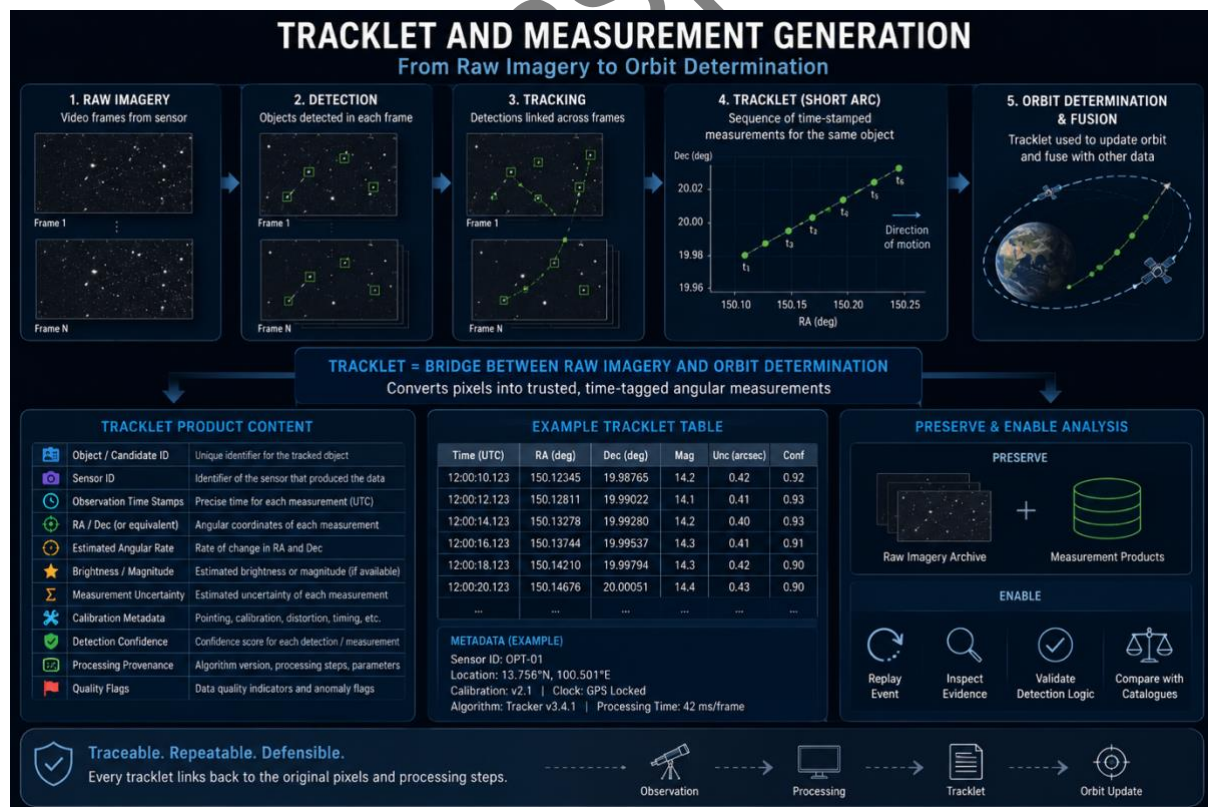


Figure 3: Tracklet analysis product output.

Calibration and timing layer

Accurate STM/SDA measurements require disciplined timing and calibration. A detection is of limited operational value unless the system knows precisely when and where it was made, how the sensor was pointed, and how image coordinates map to sky coordinates.

This layer manages:

- Sensor geolocation.
- Clock synchronisation.
- Exposure timing.
- Camera pointing and gimbal state.
- Optical distortion correction.
- Star-field registration.
- Astrometric calibration.
- Weather and image-quality metadata.
- Residual checks against known objects.

Calibration drift is a significant operational risk. The architecture should therefore include routine calibration procedures and automated quality checks, rather than treating calibration as a one-off installation task.

Orbit update and uncertainty management

Once tracklets and angular observations have been generated, they can be used to refine an object's estimated state. This may involve correlation with known objects, preliminary orbit determination, orbit update, residual analysis, and covariance estimation.

The operational value is the reduction of uncertainty. In conjunction assessment, for example, a fresh tracklet may reduce uncertainty enough to stabilise the screening result, lower the false-alarm burden, or identify a case requiring further observation. The same principle applies to debris monitoring, launch and early orbit tracking, and post-maneuvre confirmation.

This layer should produce orbit-relevant outputs rather than image-processing outputs alone. These include updated state estimates, covariance information, residuals, object association confidence, and recommended follow-up observations.

Multi-sensor fusion layer

No single sensor type provides a complete operational picture. Optical sensors can provide accurate angular evidence, but they are affected by weather, illumination, and line of sight. Radar can provide range and range-rate, but may be limited by coverage, resolution, or sensor bias. Infrared sensors may be useful in selected conditions. Space-based sensors can provide valuable geometries but introduce mission and downlink constraints.

The fusion layer combines these different measurement types into a single, confidence-rated track. NurjanaTech's data-fusion work describes a Kalman-filter-based method that receives target-position information from different sensors, including radar and electro-optical sensors, and assigns weights according to observed sensor reliability and measurement deviation.

In the STM/SDA architecture, this approach supports:

- Dynamic sensor weighting.
- Outlier rejection.
- Reduction of the influence of biased or degraded sensors.
- Combination of angular, range, range-rate, and derived measurements.

- Improved track continuity.
- Covariance reduction.
- Confidence-rated fused tracks.

The output is not merely a prettier display of the same data. It is a more defensible estimate of object state and uncertainty.

SPADAS operational decision-support layer

SPADAS provides the operator-facing decision-support environment. It ingests validated observations, tracklets, orbit updates, and fused tracks, then presents them in a form suitable for operational judgement.

SPADAS is a semi-automated platform for space safety and threat management, with functions including threat assessment, response recommendations, visual analytics, ground-sensor integration, and ground-to-space communication.

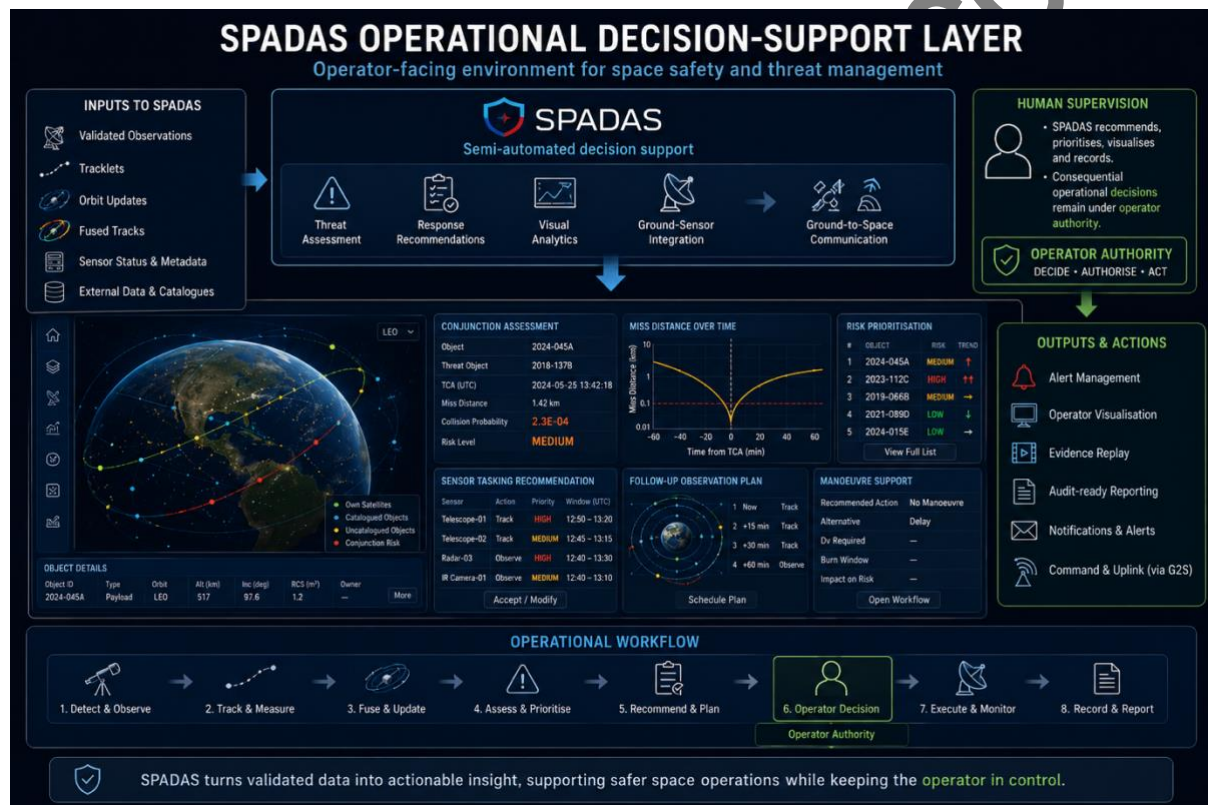


Figure 4: SPADAS operational decision support layer.

In the architecture, SPADAS supports:

- Conjunction assessment.
- Threat and risk prioritisation.
- Sensor tasking recommendations.
- Follow-up observation planning.
- Manoeuvre-support workflows.
- Alert management.
- Operator visualisation.
- Evidence replay.

- Audit-ready reporting.

The system allows flight operations that remain human-supervised. SPADAS can recommend, prioritise, visualise, and record; consequential operational decisions should remain under operator authority.

AstroTwin simulation and validation layer

Before operational use, AstroTwin provides a simulation and validation environment in which satellite behaviour, sensor-tasking logic, detection algorithms, and operator workflows can be tested. During later operations, the digital twin can also support investigation, debugging, and correction of in-flight issues.

This is important because STM/SDA systems should be tested before live operational use, particularly when detection algorithms, sensor tasking, or decision-support workflows are being introduced.

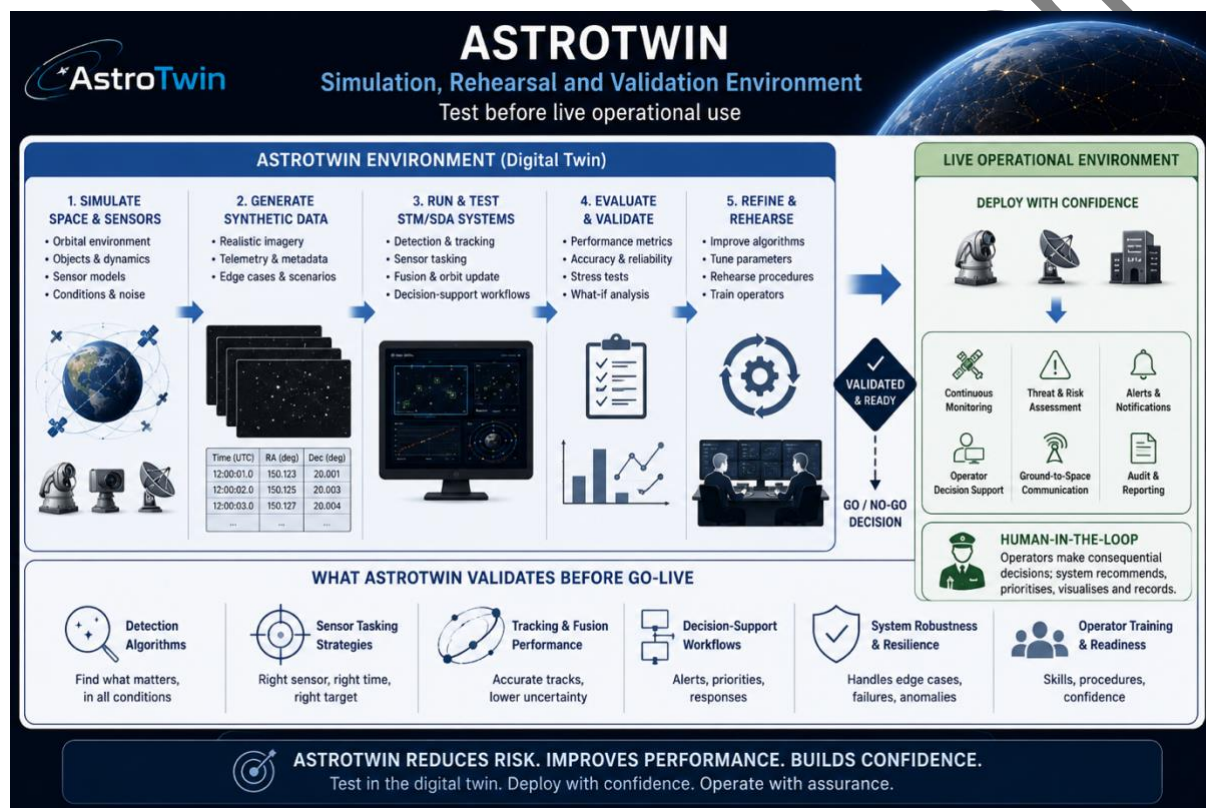


Figure 5: How AstroTwin supports parallel testing on software models.

AstroTwin is a digital twin capability for high-fidelity replication of satellite behaviour in orbit, real-time interaction between hardware, software, and the orbital environment, optical hardware-in-the-loop testing, and validation of SSA/SDA tracking algorithms.

Within the operational architecture, AstroTwin can support:

Sensor and mission rehearsal.

- Algorithm validation.
- Synthetic observation generation.
- Operator training.
- Acceptance testing.
- Anomaly simulation.

- Pre-deployment performance testing.

This reduces deployment risk and gives operators experience with representative cases before the system is used operationally.

Target end state

The target end state is an integrated STM/SDA capability in which locally deployed sensors and computing infrastructure are connected to NurjanaTech's software systems through an architecture managed and supported by Indochina Space.

The final capability will be able to observe space objects, extract measurements, generate tracklets, update orbit estimates, fuse multiple data sources, assess risk, prioritise follow-up observations, support operators, and preserve the evidence behind each decision.

AI-Enhanced Object Detection and Tracking

AI-enhanced object detection and tracking form the first analytical stage of the proposed STM/SDA architecture. This layer converts raw imagery from telescopes, electro-optical systems, infrared cameras, and future space-based sensors into structured observations that can be used for tracklet generation, orbit determination, fusion, and operator decision support.

The technical problem is straightforward to state but difficult to solve. A space object may appear in an image sequence as a faint moving point, a short streak, a glint, an intermittent return, or a low-contrast signature against a dense star field. The object may be moving slowly across the field of view, crossing rapidly through it, fading in and out because of illumination geometry, or becoming confused with background stars, sensor noise, atmospheric effects, or image artefacts. The system must therefore detect the object, associate it correctly across frames, estimate its motion, and preserve the evidence behind the detection.

NurjanaTech's electro-optical tracking work provides a useful basis for this layer. It describes an Electro-Optical Tracking System as a combination of image sensors, a positioning system, a control system, and a video tracker. The video tracker processes imagery to locate the target in the camera field of view, while the control system uses the target position error to command the pointing system and keep the object close to the image centre.

Detection and tracking as separate functions

Detection and tracking should be treated as related but distinct functions.

Detection identifies a candidate object in a single image frame. It answers the question: "Where is the object in this frame?" Tracking links detections across successive frames. It answers the question: "Is this the same object, and how is it moving?"

This distinction matters because detection errors propagate into tracking errors. A false detection may create a false track. A missed detection may break a valid track. A poor association between frames may join observations from different objects. The system must therefore combine image-processing methods, motion logic, confidence scoring, and operator review thresholds.

Detection methods

Different objects and observation conditions require different detection methods. NurjanaTech's EOTS systems identify several classical detection approaches, including edge detection, centroid detection, and contrast detection. Edge detection is useful when a defined feature or boundary can be followed. Centroid detection is useful when the whole object can be detected reliably. Contrast detection is useful when the target appears as a blob with sufficient contrast against the background.

For STM/SDA, these methods can be extended to the specific conditions of astronomical and space-surveillance imagery. Candidate detection methods may include:

- Contrast-based detection for small bright points or glints.
- Blob detection for compact unresolved objects.
- Streak detection for objects moving during exposure.
- Frame differencing for moving objects against a star background.
- Background subtraction for stationary or predictable backgrounds.
- Correlation tracking for objects with consistent motion across frames.
- Machine-learning classification for difficult or ambiguous detections.

The system should not assume that one method is always best. The appropriate method depends on target brightness, angular rate, exposure length, sensor type, background density, atmospheric conditions, and expected object motion.

Automatic algorithm selection

In traditional electro-optical tracking, experienced operators often select the tracking method and tune the tracking behaviour. This introduces variability and can slow operations. NurjanaTech addresses this by using machine learning and deep learning to select the most suitable detection or tracking algorithm automatically according to the scenario. NurjanaTech detection software uses a convolutional neural network to select detection and tracking algorithms from imagery collected across different mission types, target classes, visibility conditions, backgrounds, and sensor bands.

For STM/SDA, the same concept is directly relevant. The system can evaluate the current observation context and select the most suitable detection approach. For example, it may treat a faint point source differently from a streaked object, a high-angular-rate target differently from a slow GEO object, and an infrared detection differently from a visible-band telescope image.

This reduces dependence on manual operator selection. It also makes the system more consistent across different operators, sites, sensors, and observation campaigns.

Adaptive tracking and pointing control

Object detection alone is not enough. A useful observation often requires the object to remain in the sensor field of view long enough to generate a valid tracklet. This is particularly important for follow-up observations, launch and early orbit support, fast-moving objects, and high-interest targets.

NurjanaTech's uses adaptive control to keep the tracked object close to the image centre. The system uses the position error between the target and the image centre to command the pointing system. The software employs a neural network to tune proportional-integral control gains automatically, based on target velocity and image-based position.

In the proposed STM/SDA architecture, this supports dynamic sensor pointing. A telescope or electro-optical system can be cued to an expected object position, detect the object, then adjust pointing to maintain the observation. This improves the probability of generating complete tracklets and reduces the risk that the object exits the field of view before enough measurements have been collected.

Handling difficult observation conditions

Space-object tracking is often limited by observation quality. The system must handle:

- Faint targets.
- Short visible arcs.

- Object streaking.
- Star-field clutter.
- Cloud, haze, or atmospheric seeing.
- Sensor noise and hot pixels.
- Glints and brightness variation.
- Nearby objects or multiple candidates.
- Incorrect catalogue association.
- Timing or calibration errors.

This is where AI-enhanced processing has practical value. Machine learning can help classify candidate detections, select the correct tracking method, identify anomalous measurements, and support quality scoring. Classical methods remain important, but AI can help choose and combine them more effectively.

Earlier NurjanaTech satellite-imagery work provides a useful supporting example. In a different application domain, its S2IGI hotspot-detection algorithm used machine learning to model expected satellite radiance behaviour and detect anomalies against that model. Machine-learning models matched real brightness-temperature data more closely than the polynomial model and detected more validated hotspots. For STM/SDA, the relevant point is the method: model the expected background, identify deviations, and use machine learning to improve detection under noisy sensor conditions.

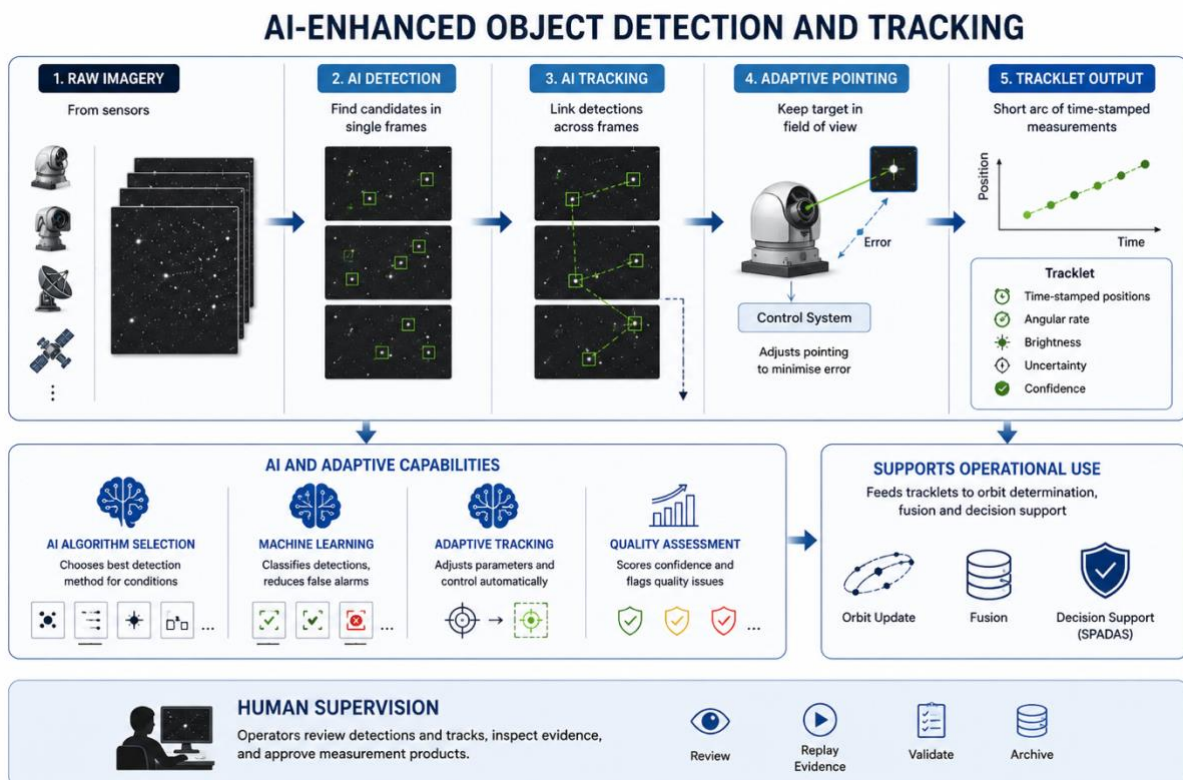


Figure 6: The AI-enhanced orbit determination process.

From image pixels to measurement products

The output of the detection and tracking layer should not be a screen annotation alone. It must produce structured measurement products.

For each candidate object, the system should generate:

- Frame-level object position.
- Time stamp for each observation.
- Sensor identifier.
- Image coordinates.
- Calibrated angular coordinates.
- Estimated angular rate.
- Brightness or magnitude estimate where available.
- Detection confidence.
- Tracking confidence.
- Quality flags.
- Processing provenance.

These outputs then feed the tracklet-generation process. The tracklet becomes the bridge between the raw imagery and orbit determination. Without this step, the system remains a visual monitoring tool. With it, the system becomes part of an operational STM/SDA measurement chain.

Human-supervised automation

The purpose of AI-enhanced detection and tracking is to improve measurement quality and reduce operator burden. **It should not remove operator authority from consequential decisions.**

The system should therefore include confidence thresholds, evidence replay, quality flags, and human review pathways. Low-confidence detections should be marked for review. Ambiguous associations should retain provenance. Operators should be able to inspect the original imagery, review the detection logic, compare outputs against catalogues, and approve or reject measurement products before they are used in high-consequence operational workflows.

This approach preserves the value of automation while keeping the system defensible. AI detects, tracks, ranks, and records. Operators retain control over operational judgement.

Ground-Based and Space-Based Observation within the SPADAS SDA Layer

The proposed SDA architecture combines ground-based and space-based observation within one operational framework. Ground sensors provide scalable and maintainable observation capacity. Space-based sensors add viewing geometries that are unavailable from the ground and reduce dependence on weather, atmosphere, and site visibility. SPADAS acts as the operational layer that brings these sources together.

Ground-based observation is the practical starting point. It may include optical telescopes, electro-optical tracking systems, infrared sensors, radar interfaces, timing systems, edge-processing hardware, communications links, and operator workstations. These sensors support wide-field search, narrow-field follow-up, high-rate tracking, debris monitoring, post-manoeuve confirmation, and conjunction assessment.

Space-based observation extends the architecture. Hosted payloads, CubeSats, onboard cameras, **event-based cameras**, or **neuromorphic-processing systems** can observe objects from different orbital geometries and provide complementary data to ground sensors. NurjanaTech's portfolio identifies NEBULA as an SDA solution using event-based cameras and neuromorphic processing, and JANASAT-1 as a CubeSat platform for space surveillance and tracking payload qualification.

The value of the architecture lies in combining these sources. A ground telescope may provide angular measurements from one line of sight, while a space-based sensor may observe the same object from another geometry. Radar, where available, can add range and range-rate information. These inputs can then be fused to improve track confidence, reduce uncertainty, and prioritise further observations.

NEUROMORPHIC PROCESSING FOR VIDEO ANALYSIS

Event-Based Cameras vs Standard Cameras

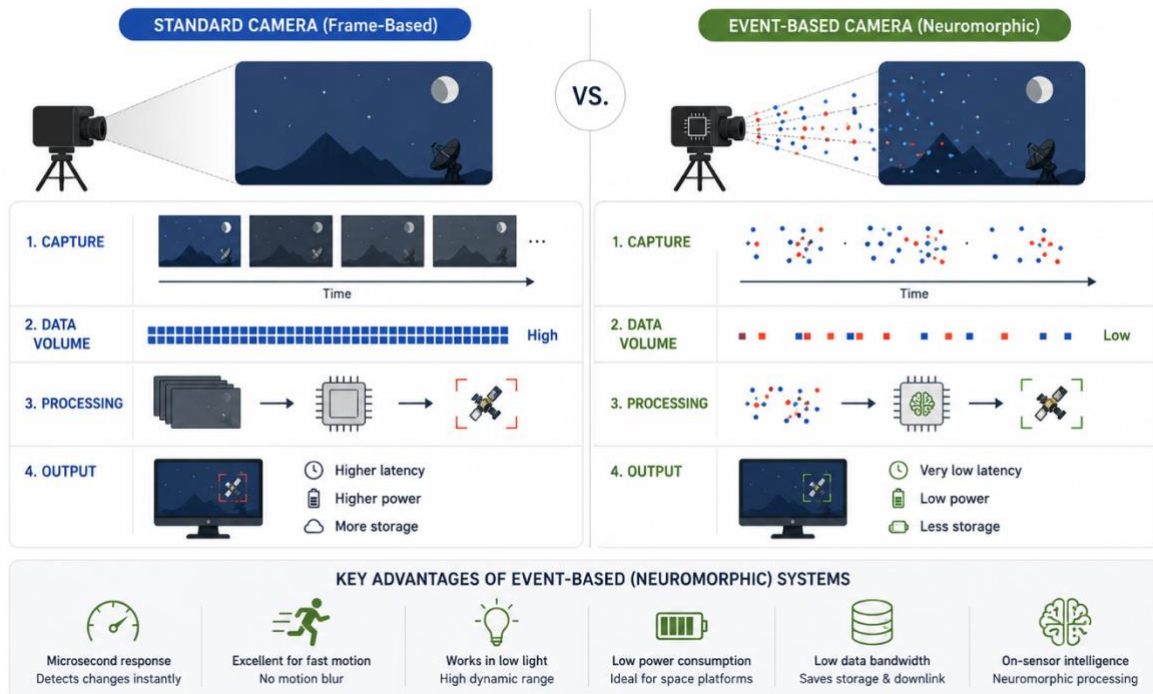


Figure 7: Neuromorphic capture (capturing only changes with event-based cameras) reduces computing power needed to analyse images.

SPADAS sits above the sensor network. It ingests validated observations, tracklets, orbit updates, fused tracks, sensor status, and metadata. It then presents operators with a common operational picture, risk prioritisation, follow-up observation recommendations, sensor-tasking options, manoeuvre-support information, alerts, visual analytics, and audit-ready reporting. SPADAS is described as a semi-automated space safety and threat-management platform with threat assessment, response recommendations, visual analytics, ground-sensor integration, and ground-to-space communication functions.

The operational workflow is:

Observe → process → validate → fuse → assess → recommend → operator decision

SPADAS can recommend, prioritise, visualise, and record. Consequential operational decisions remain under human authority. This keeps the system practical: sensors provide coverage, AI analytics produce measurements, fusion improves confidence, and SPADAS gives operators the evidence needed to act responsibly.

Strategic Benefits and Operational Value

The value of an STM/SDA capability is measured by the quality of the decisions it supports. A useful system must do more than display orbital data or sensor feeds. It must convert observations into trusted measurement products, reduce uncertainty, preserve evidence, and present operators with information they can use under time pressure.

The proposed Indochina Space and NurjanaTech architecture provides value at several levels.

- **First, it improves the use of observation hardware.** Telescopes, electro-optical sensors, infrared cameras, radar feeds, and future space-based sensors all have strengths and limitations. Used

separately, they provide partial views of the orbital environment. Integrated through AI-enhanced processing and multi-sensor fusion, they become part of a coherent operational picture.

- **Second, the architecture strengthens the measurement chain.** Raw imagery is converted into detections, tracklets, calibrated angular measurements, confidence-rated tracks, and orbit-relevant products. This allows operators to work from structured evidence rather than isolated images or unprocessed sensor outputs.
- **Third, it supports faster and more consistent analysis.** AI-enhanced video processing can help identify candidate objects, track them across frames, reduce false detections, and support the generation of repeatable measurement products. This reduces dependence on manual interpretation and helps maintain consistency across sensors, operators, and observation conditions.
- **Fourth, the architecture improves uncertainty management.** Multi-sensor fusion allows different measurement types to be combined, with degraded or biased inputs weighted appropriately. This is important for conjunction assessment, debris monitoring, post-manoeuve confirmation, and high-interest object tracking, where operators need to know whether fresh observations have reduced uncertainty enough to support action.
- **Fifth, SPADAS provides the operator-facing decision-support environment.** It can combine validated observations, tracklets, orbit updates, fused tracks, sensor status, and metadata into a common operational picture. This supports threat assessment, risk prioritisation, sensor tasking, follow-up observation planning, alert management, evidence replay, and audit-ready reporting.
- **Sixth, AstroTwin adds a validation and rehearsal capability.** Detection algorithms, sensor-tasking logic, decision-support workflows, and operator procedures can be tested in simulation before operational use. This reduces technical risk and gives operators a way to understand system behaviour before relying on it in live conditions.

For Thailand, the additional value lies in local systems integration. Indochina Space provides the practical bridge between imported specialist software and locally deployed capability. Hardware must be selected, sourced, installed, timed, calibrated, secured, connected, and supported. This integration role is essential if advanced STM/SDA software is to become a working operational system rather than a standalone technology package.



Figure 8: A summary of the strategic benefits to expanded SDA operations.

The result is a scalable public-interest capability: better use of sensors, stronger measurement products, more transparent decision support, and a clearer path from observation to operational awareness. The system remains human-supervised. AI, fusion, simulation, and SPADAS support the operator; they do not replace operator authority.

Conclusion

Space Traffic Management and Space Domain Awareness depend on the ability to convert observations into trusted operational intelligence. Raw imagery, sensor feeds, and catalogue entries have value, but they become operationally useful only when they are transformed into calibrated measurements, tracklets, fused tracks, uncertainty estimates, risk assessments, and evidence that operators can inspect and trust.

The proposed Indochina Space and NurjanaTech approach addresses this requirement through an integrated architecture. NurjanaTech provides the specialist technology stack: AI-enhanced video analysis, automatic object detection and tracking, tracklet extraction, multi-sensor fusion, AstroTwin simulation, and SPADAS operational decision support. Indochina Space provides the local systems-integration function in Thailand, sourcing and integrating the required hardware, coordinating deployment, supporting calibration and testing, and ensuring that the system can operate within the customer's local environment.

The value of this approach lies in the full observation-to-decision chain. Sensors collect the evidence. AI-enhanced processing detects and tracks objects. Tracklets and calibrated measurements support orbit determination. Fusion reduces uncertainty and improves confidence. AstroTwin allows algorithms, workflows, and procedures to be tested before operational use. SPADAS presents operators with a common operational picture, risk prioritisation, follow-up observation options, alerts, evidence replay, and audit-ready reporting.

This architecture is designed to remain human-supervised. AI, fusion, simulation, and decision-support software improve the quality, speed, and consistency of analysis, but consequential operational decisions remain with the

operator. This is essential for a domain where uncertainty, mission risk, and accountability must be handled carefully.

For Thailand and the wider region, the combined capability offers a practical route to stronger STM and SDA: better exploitation of observation hardware, clearer measurement products, improved uncertainty management, and a locally integrated operational system. The result is a scalable approach to space safety and orbital awareness, built around trusted measurements, defensible analysis, and operator-controlled decision making.

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