CENTER FOR ADVANCED AVIATION SYSTEM DEVELOPMENT (CAASD)

DRAFT

Strawman Functional Architecture for Airborne Surveillance and Separation Assurance Processing (ASSAP)

MITRE/CAASD

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Outline

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ASSAP Subsystem

- **ASSAP subsystem represents the *surveillance* and *application-specific* processing functions of ASA.**
  - **ASSAP surveillance processing consists of correlation and track processing of ADS-B, ADS-R, TIS-B and TCAS traffic reports.**
  - **ASSAP application processing provides the application-specific processing of all ASA applications.**
- **ASSAP maintains the interface to/from the CDTI Display and Control Panel subsystem.**

Source: ASA MASPS

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ASA MASPS: High Level ASSAP Requirements

- **Surveillance Processing:**
  - **Establish tracks from ADS-B and TIS-B traffic reports.**
  - **Cross-reference traffic from different surveillance sources (ADS-B, TIS-B, TCAS).**
  - **Estimate track state (e.g., position, velocity), and track quality.**
  - **Delete tracks that are beyond the maximum allowable coast time for any ASA application.**
- **Application Processing**
  - **Determine the appropriateness of track information for various applications and forward it to the CDTI.**
  - **Perform alerting functions (i.e., CD).**

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ASA MASPS: On Track Estimation

- **The ASA MASPS leaves it up to the ASAS MOPS to determine how to estimate the track when multiple sources provide updates for the same A/V.**
  - **ASSAP *shall* (R3.169) provide a tracking function. The tracking function *shall* (R3.174) include track state based on one or more surveillance source inputs.**
  - **The estimation *may* combine information from different data sources in order to improve the track state estimate. (ASA MASPS, p. 109)**
  - **Note: The fusion of TCAS measurements with ADS-B or other data is the subject of continuing debate and will be treated in the ASAS MOPS. (ASA MASPS, p. 109)**

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Proposed ASSAP Architecture for Track Estimation

- Reviewed typical tracker architectures for multi-sensor trackers.
- Typical multi-sensor trackers optimize for detection and track continuity performance.
  - Sensor coverage overlap provides multiple looks at target (i.e., higher update rates) from different angles.
  - Higher update rate improves detection and multiple geometries improves track quality (due to triangularization).
  - The architectures for multi-sensor trackers fall under three categories
    - Source-Level Tracker
    - Central-Level Tracker
    - Hybrid Tracker
- ASSAP surveillance sources (i.e., TIS-B and ADS-B) are employed as mutually exclusive services.
  - Under the Fundamental TIS-B Service, only non-equipped A/V are transmitted.
  - The rarity of simultaneous reporting of an A/V by both TIS-B and ADS-B services does not warrant the complexity of “fusion” tracking.
  - The rare case when both services report on the same A/V, has to be detected by ASSAP to mitigate sending dual tracks to the CDTI for the same A/V.
- Developed an adaptation of a Source-Level Tracker for ASSAP to process ADS-B and TIS-B surveillance sources.

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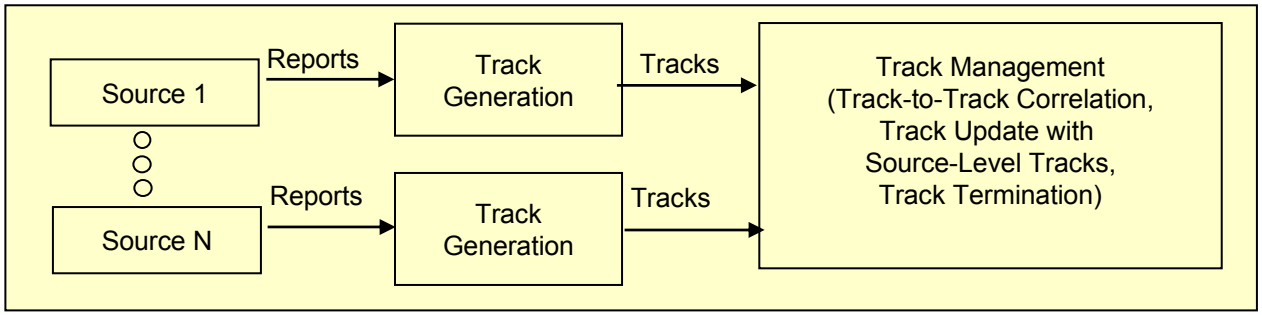
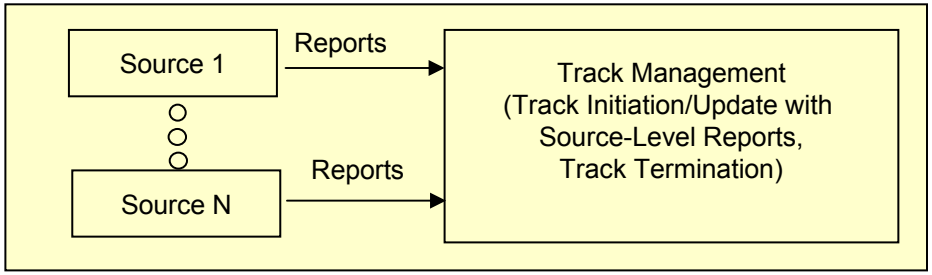
Typical Architectures for Multi-Sensor Trackers: Source-Level Tracker, Central-Level Tracker, Hybrid Tracker

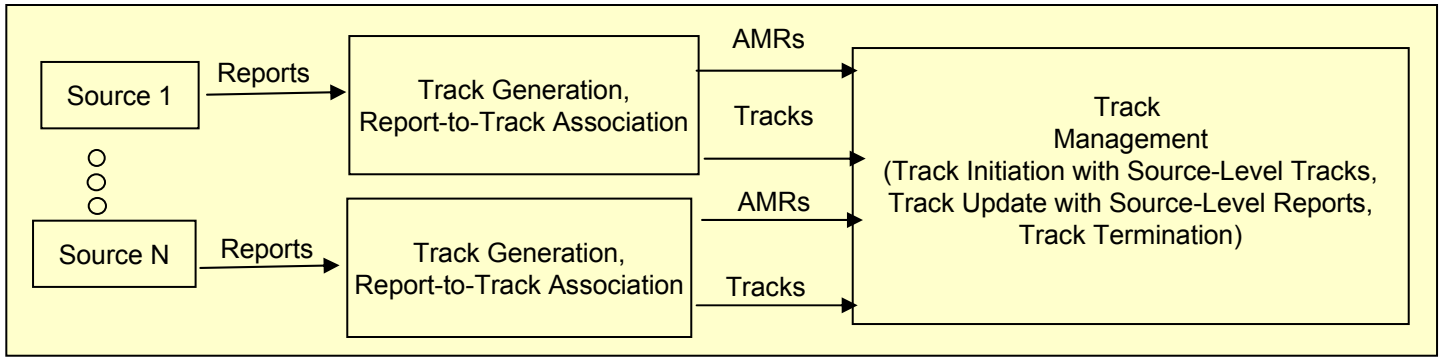
Source-Level Tracking
Forms Sensor Tracks and then Combines the Tracks



Central-Level Tracking Forms Tracks from Source Reports



Hybrid Tracking
Maintains Source-Level Tracks and Uses Associated Measurement Reports (AMRs) to Update Central-Level Tracks



Proposed ASSAP Track Estimator Architecture- for ADS-B & TIS-B Sources

- **Proposed adaptation of Source-Level Tracker for ASSAP with these major functions:**
  - **Establish tracks from ADS-B/ADS-R and TIS-B sources separately (Track Generation).**
  - **Perform correlation between source-level tracks (ADS-B/ADS-R tracks and TIS-B tracks) to detect when an A/V is tracked by multiple sources (Inter-Source Correlation).**
  - **Select the best track when source-level tracks from ADS-B and TIS-B sources correlate (Best Track Selection).**
  - **Perform correlation between ownship track and TIS-B track to remove "shadow" on ownship (Inter-Source Correlation).**
  - **Perform correlation between TCAS reports and current source-level tracks and tag the source-level tracks with the correlation status (Inter-Source Correlation).**

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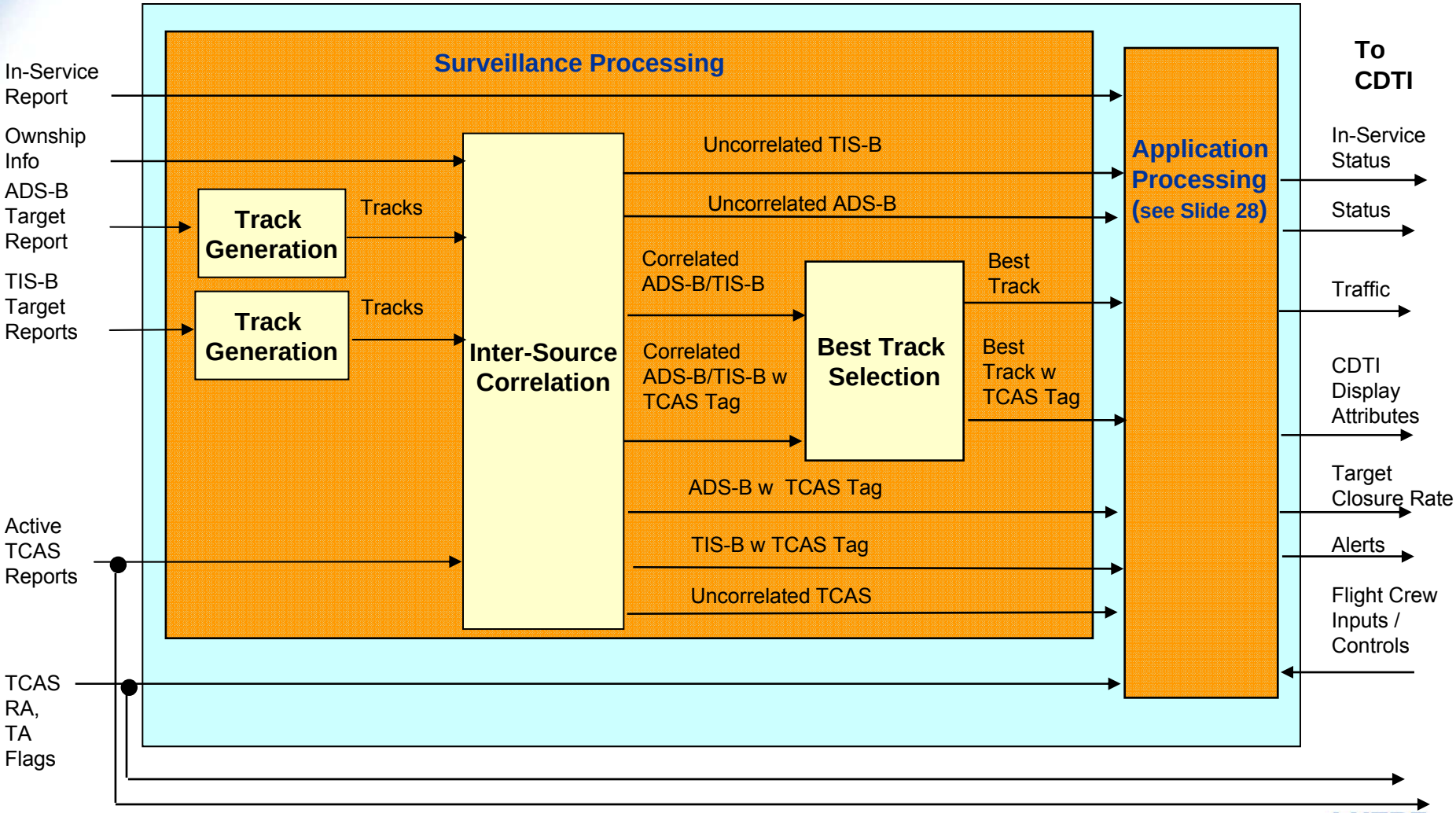
Architectural Approach – Source-Level Tracking with Best Track Selection & TCAS Tagging



Proposed Track Generation Basics

- **Report-to-Track Association**
  - Match up (perhaps multiple) existing tracks with received report.
- **Report-to-Track Resolution**
  - Final track to report assignment or track initiation assignment.
- **Update (or Filter)**
  - Incorporate received report into estimation of track state and track uncertainty.
- **Track Initiation**
  - New tracks created using reports not associated with existing tracks.
- **Background Processing**
  - **Termination**
    - Delete track records when reports no longer received.
  - **Prediction**
    - Estimate track position and uncertainty where it "should" be at some future time (CDTI refresh times)
  - **Track Splitting**
    - Detect duplicate target IDs (i.e., multiple A/Vs erroneously assigned the same address) and assign unique track IDs.
  - **Track Merging for TIS-B only**
    - Detect dual tracks (i.e., one A/V assigned multiple addresses) and merge into one track (optional).

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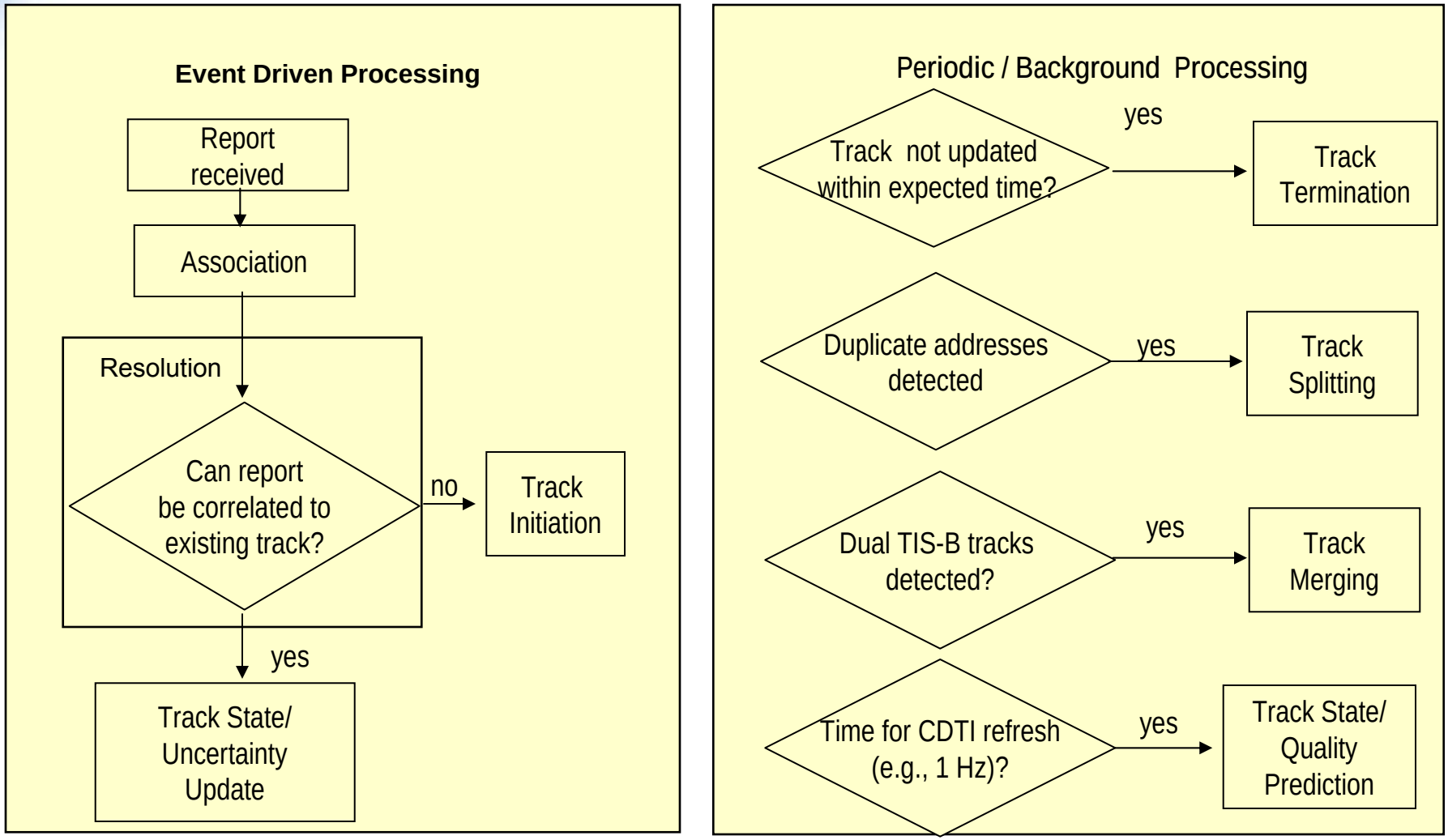
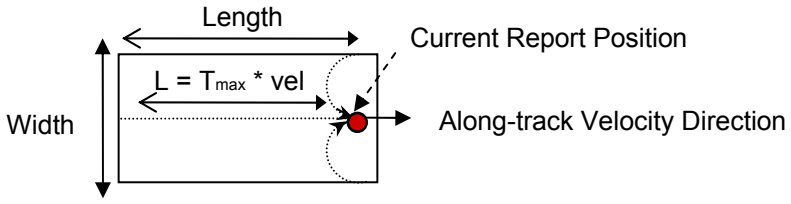
Track Generation Flow



Sub-Functions of Source-Level Track Generation

1. **Report-to-Track Association (traced to ASA MASPS R3.169, R3.170, R3.185)**
   - **Means by which reports are associated with existing tracks. A validation region based on spatial correlation is proposed to reduce the number of candidate tracks that can be reasonably associated with the latest surveillance report.**
   - **The report-to-track association function *shall* pass spatial correlation. Rationale: It cannot be based solely on a match between Report ID and existing Track ID.**
     - **Due to installation errors (e.g., installer left default value or pilot entered wrong ID) duplicate IDs have been observed.**
     - **UAT Link: Nothing precludes A/Vs with duplicate IDs to be successfully decoded and presented to ASSAP, so a validation region is recommended. (1090ES Link: The avionics receiver cannot decode A/Vs with duplicate IDs and most likely will drop duplicate ID targets.)**
   - **Spatial correlation *may* be accomplished with one or both types of windows**
     - **Candidate Window (CW) - a coarse window referenced to the position of the new Report that bounds the volume where the target could have been when it was last updated.**
       - **The CW length is defined in the along-track velocity direction of the Report as the product of along-track velocity and Tmax, where Tmax accounts for a miss (e.g., ADS-B:Tmax = 2.1 s, TIS-B: Tmax = 24.1 s)**
       - **The CW width is defined in the cross-track velocity direction to account for a constant velocity (= Report speed) turn at a nominal rate (e.g., 3 deg/sec) for Tmax**
       - **The CW height is defined in the direction perpendicular to the horizontal plane to account for a nominal climb/descent rate for Tmax.**



Sub-Functions of Track Generation (cont'd)

- Association Window - a finer window that predicts candidate tracks to the TOA of the Report and takes into account the uncertainty of both the report and the candidate track may be employed to further define the validation region (for details see backup page 46).

2. Report-to-Track Resolution
   - Rules that determine when a report updates an existing track or initiates a new track.
     - The report *shall* be resolved to update a track when a track falls within the validation region and its track ID matches the report ID.
     - The report *shall* be resolved to initiate a new track when no track with a track ID that matched the report ID can be found within the validation gate.
     - *Optional: TIS-B Merge Function included*: When a TIS-B track falls within the validation region of a TIS-B Report and there is no match between the track and report IDs, this correlation *shall* be noted as an update to the "M-out-of-N" pattern that the track keeps for that report. This correlation pattern is used by the Background Merge Function. (See Slide #18)
3. Track Initiation (traced to MASPS R3.177)
   - A new track *shall* be initiated when none of the existing tracks can be associated with the current Report.
   - The track *shall* be initiated after one report.
     - Typically a track is initiated after M detections out of N opportunities to mitigate false track initiation. However, this does not appear to be necessary for ASSAP: a TIS-B report has been pre-tracked (by a ground surveillance tracker) to mitigate false track generation (e.g., due multipath); an ADS-B Report is not false unless it is intentionally spoofed. (I think mitigating spoofing on the A/V is outside the scope of this MOPS.)
   - The new track ID *shall* be set to the report ID.

Sub-Functions of Track Generation (cont'd)

4. **Track Update & Track Prediction (traced to R3.176, R3.186)**
   - **ASSAP is required to *predict* track state and quality information contained in its *reports* from ADS-B and TIS-B sources at arbitrary times (i.e., between report times).**
     - **ASSAP *shall* (R3.186) provide current traffic state position info to the interface with the CDTI with at least a 1 Hz rate.**
     - **ASSAP *shall* (R3.176) estimate the quality of the track state info that is maintained in the track file, and maintain quality measures for the track state info, as indicated in Table 3-15.**
   - **Constraint**
     - **The ASSAP does not ingest measurements but tracked/filtered reports (i.e., consecutive reports are correlated).**
     - **Standard tracking techniques that expect measurements as input are not necessary.**
   - **Proposed Filtering Method: A novel *degenerate Kalman Filter* that**
     - **Applies standard Kalman Filter equations to *predict* track state and quality.**
     - **Deviates from the standard Kalman Filer in *updating* track state and quality. Rationale: A "filter" is used to smooth the state using the coarse and noisy measurement. However, ADS-B and TIS-B are not pure measurements but pre-filtered reports. Therefore, recommendation is to set**
       - **State update = received report state**
       - **State uncertainty = covariance derived from reported NAC**
     - **Proposed Coordinate frames**
       - **Track prediction/update: ENU centered on current ownship position**
       - **Track file: WGS-84**

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Major Functions of Track Generation (cont'd) - Overview of Proposed Really Degenerate Kalman Filter (Prediction Only)

	Kalman Filter	Degenerate Kalman Filter
Innovation	$z_k = y_k - H_k \tilde{x}_k$	**Not used**
State Estimate	$\hat{x}_k = \tilde{x}_k + Kz_k$	**Set to latest Report State Vector**
State Prediction	$\tilde{x}_{k+1} = \Phi_k \hat{x}_k + f_{k+1}$	$\tilde{x}_{k+1} = \Phi_k \hat{x}_k \quad (\text{Eq. } 1)$
Kalman Gain	$K_k = \tilde{P}_k H_k^T \left[H_k \tilde{P}_k H_k^T + R_k \right]^{-1}$	**Not used**
Estimated Covariance	$\hat{P}_k = \left[1 - K_k H_k \right] \tilde{P}_k$	**R_k, derived from Report accuracy (Note 1)**
Predicted Covariance	$\tilde{P}_{k+1} = \Phi_k R_k \Phi_k^T + Q_k$	$\tilde{P}_{k+1} = \Phi_k R_k \Phi_k^T + Q_k \ (\text{Eq. } 2)$

Notes:

1. $R_{k_i} = \begin{bmatrix} \sigma^2_{NAC_E} & 0 \\ 0 & \sigma^2_{NAC_V} \end{bmatrix}$, i: ENU coordinates

   For EN coordinates: NAC is circular horizontal accuracy,
   e.g., if NAC_P = 4, Rc = 1852 m (DO-289 Table 3-6) as the 95% uncertainty bound. To derive the covariance matrix multiply the Rc by a factor of 0.4085 and square the product.

   For the U coordinate: NAC is the vertical accuracy.
   For NACp ≥ 9, derive the covariance from the VEPU in Table 3-6, for lower NAC_P values use a conservative value.

2. $\Phi_{k_i} = \begin{bmatrix} 1 & \Delta T \\ 0 & 1 \end{bmatrix}$, ΔT = Update Interval

   i: ENU coordinates

3. Q= Process Noise Matrix (adaptable)

Discussion: Estimating Quality of Track (R3.176, R3.187)

- **ASA requires estimating track state and quality at 1Hz update rate (R3.178). Track quality is indicated by Integrity (NIC/SIL) and Accuracy (NAC).**
  - **NAC: Two possible NAC predictors between report updates.**
    - **Allow for the uncertainty to grow with time**
      - **Use Degenerate Kalman Filter to predict the track covariance to current time.**
        - » **Update covariance based on NAC (see Slide 15, Note 1). Since each NAC index corresponds to an interval of 95% containment radii, the extrapolation can start with the largest containment radius (most conservative) or with the middle containment radius.**
        - » **Extrapolate covariance to current time (see Slide 15, Equation 2)**
        - » **Convert extrapolated covariance component to horizontal NAC index using a simple conversion: (1) take the square root of the covariance component, (2) multiply by 2.4477 to find the containment radius, and (3) find corresponding NAC index in Table 3-6 of ASA MASPS.**
    - **Keep the uncertainty static regardless of the time since last update (which could be up to 12 s for TIS-B).**
  - **NIC/SIL: Extrapolation of NIC to current time - not yet addressed.**

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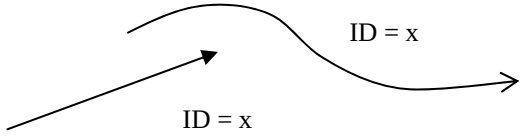
Background Processor – "Splitting" Tracks for Duplicate Addresses

Example: Installer left default value or pilot entered wrong ID.



- **Background: Mode S SSR data with duplicate addresses recorded at Dallas Airport.**
  - **1090ES Link**
    - **Duplicate Mode S addresses may not be adequately resolved in the avionics w/o changes to the Link MOPS (DO-260A presumes addresses are unique).**
    - **The Report Assembly for 1090ES ADS-B Messages depends on uniqueness of Mode S addresses to generate the report (otherwise the content of the reports are erratic). Hence, 1090 ES targets with duplicate addresses will typically be dropped prior to ASSAP.**
  - **UAT Link**
    - **Since an ADS-B report can be generated from a single UAT message, nothing precludes reception of duplicate addresses at ASSAP.**
- **The Background Processor *shall* search the track files (at a source level, i.e., for ADS-B and TIS-B tracks) and ensure that each track has a unique track ID.**
- **The criteria for splitting tracks with duplicate IDs into tracks with distinct track IDs *shall* be:**
  - **Spatial Correlation: distance between the track positions > *Thr_distance* (adaptable)**
  - **Speed Inconsistency: difference in speed > *Thr_speed* (adaptable)**
  - **Ground Track Inconsistency (optional): difference in Ground Track > *Thr_GT* (adaptable)**
- **A new unique local track ID *shall* be assigned to the track with the worse quality (based on NIC, then NAC). This track *shall* accept updates from reports of the previous ID #. (Both track can be updated with the same report ID. Since they are different targets and spatially separated , the report will associate with only one track.)**

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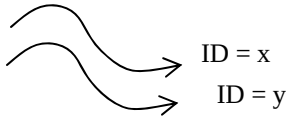
Background Processor - Track Merge Logic for Dual TIS-B Tracks

Examples:
TIS-B: Handoff problems in overlapping Service Volumes of distributed ground surveillance trackers..
TIS-B: Registration errors between multiple sensors.



- **Background: TIS-B can generate dual tracks for a single target (e.g., due to handoff problems in overlapping service volumes of distributed ground surveillance trackers, or registration errors between multiple sensors in a multi-sensor environment. The Background Merge function would detect these situations and merge the tracks into a single track.**
- **A sliding detection pattern (M detections out of the last N opportunities) *shall* be maintained between each track and reports (of different IDs) that have been spatially associated.**
- **The track with the worst NAC *shall* be deleted when:**
  - ***Corresponding M/N patterns for both tracks exceed a threshold (adaptable)***
  - ***Speed difference < THR_s***
  - ***Ground Heading difference < THR_hdng* (optional)**
- **After a merge has been determined, reports with both IDs *shall* be allowed to update the "merged" track.**

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Background Processor - Track Termination (R3.178)

- **The tracking function *shall* (R3.178) terminate a track when the maximum coast interval (Table 2-3, row 17) has been exceeded for all of the applications for which the track is potentially being used.**

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Proposed Inter-Source Track Correlation

- **ASA MASPS Requirements:**
  - **R3.179: If TCAS data is to be integrated on the CDTI, ASSAP *shall* correlate the TCAS tracks with its internal tracks to the extent practicable.**
  - **R3.181: For correlated TCAS tracks, ASSAP *shall* provide that information in the track file (see Table 3-4).**
  - **R3.182: The criterion for minimizing the probability of mismatching TCAS/ADS-B tracks, or not matching TCAS/ADS-B tracks *shall* be defined in the ASAS MOPS.**
  - **R3.183: ASSAP surveillance processing *shall* cross-correlate the traffic from TIS-B and ADS-B reports supplied by the ADS-B receiver.**
  - **R3.184: The criterion for minimizing the probability of mismatching TIS-B/ADS-B tracks, or not matching TIS-B/ADS-B tracks *shall* be defined in the ASAS MOPS.**
- **Basic Functions of Proposed Inter-Source Correlation**
  - **Correlate between ADS-B and TIS-B (traced to R3.183, R3.184).**
  - **Correlate between ADS-B/TCAS and TIS-B/TCAS (traced to R3.179, R3. 181, R3.182).**
  - **Correlate between ownship and TIS-B track and remove track (shadow). (Not explicitly traceable, but seems like a good idea.)**
    - **A TIS-B track that correlates with ownship *shall* be removed.**

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Proposed Inter-Source Track Correlation (cont'd)
Truth Table: Multi-Source Correlation

Truth Table: Multi-Source Correlation

Sources			Output	Requisite Conditions
ADS-B	**TIS-B**	**TCAS**		
yes	yes	yes	Best Track w TCAS Tag	(1) Target is ADS-B equipped, (2) Ground Surveillance Processor fails to suppress TIS-B for this target, (3) target is equipped w TCAS transponder.
yes	yes	no	Best Track	Target is ADS-B equipped, Ground Surveillance fails to suppress TIS-B for this target.
yes	no	yes	ADS-B w TCAS Tag	Target is ADS-B equipped and equipped w TCAS transponder.
yes	no	no	Uncorrelated ADS-B	Target is ADS-B equipped.
no	yes	yes	TIS-B w TCAS Tag	Target is within TIS-B coverage and equipped w TCAS transponder
no	yes	no	Uncorrelated TIS-B	Target is within TIS-B coverage.

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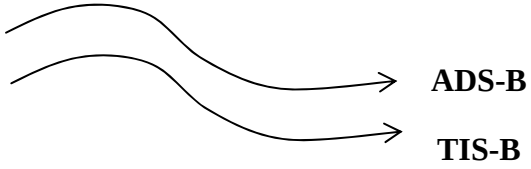
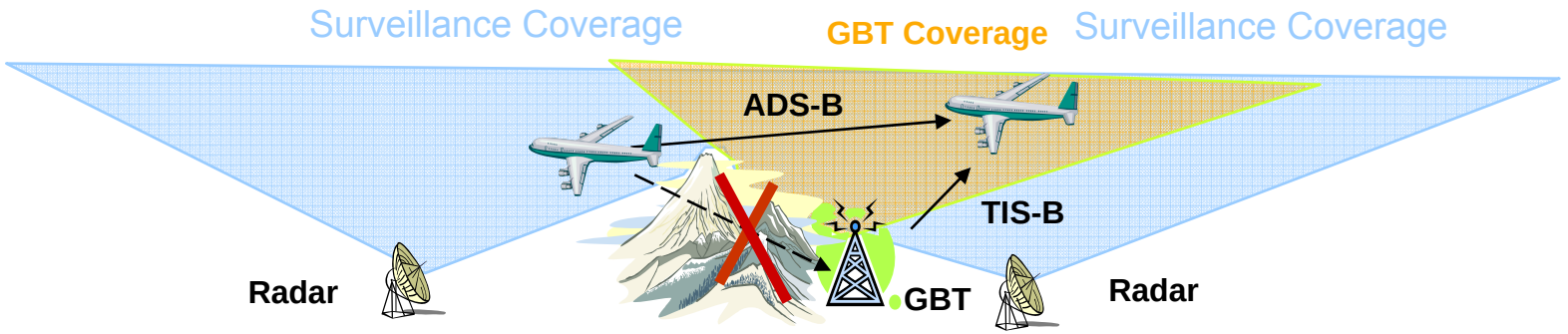
Proposed Inter-Source Track Correlation (cont'd)
ADS-B/TIS-B Correlation

- **Motivation for Correlation between ADS-B and TIS-B (based on R3.172)**
  - **Detects TIS-B shadows due to**
    - **TIS-B Ground Subsystem's failure to associate ADS-B tracks with tracks generated from other sources (e.g., radar).**



    - **ADS-B air-to-ground is limited due to line-of-sight blockage; air-to-air ADS-B is unhindered.**



- **Correlation between ADS-B and TIS-B tracks *shall* be established in the following order**
  - **Track ID is the same (unlikely to be the case).**
  - **Call Sign is the same (optional input).**
  - **Spatial correlation and velocity consistency is met over M-out-of-N most recent updates.**

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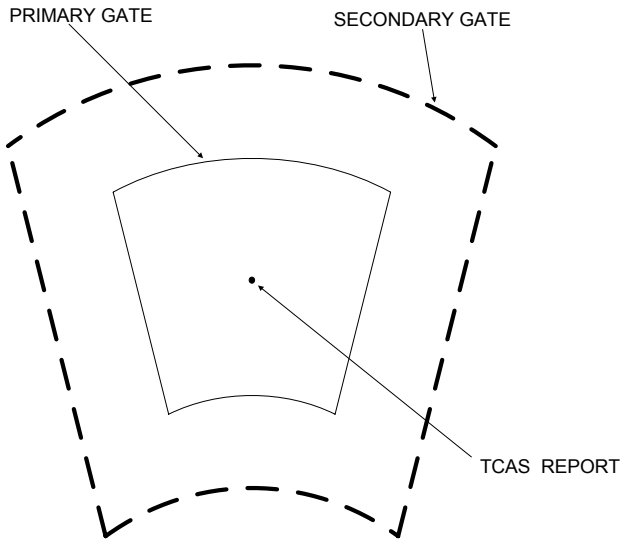
Proposed Inter-Source Track Correlation (cont'd) - Correlation between TCAS Reports and ADS-B or TIS-B Tracks

- **Purpose: indicate to the CDTI when surveillance tracks correlate with TCAS Reports.**
- **Cross-referencing of tracks with TCAS reports *shall* be performed via spatial correlation with one or two gates:**
  - **Primary gate based on TCAS report's range and source type (i.e., TIS-B or ADS-B/ADS-R)**
  - **Secondary gate which is larger (adaptable) and provides a coarse correlation**



GATE SIZE IS RELATED TO SOURCE TYPE AND TCAS Report RANGE

+
OWNSHIP POSITION

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Proposed Inter-Source Track Correlation (cont'd) - Potential TCAS Correlation Tags

- **TCAS Correlation**
  - **Performed during track association within primary gate when: (1) a single source-level track is found, or (2) multiple tracks are found and one of them matches the TCAS address (i.e., Mode S address is available from TCAS report).**
- **Coarse Correlation**
  - **Performed during track association within secondary gate when: (1) a single source-level track is found, or (2) multiple tracks are found and one of them matches the TCAS address (i.e., Mode S address is available from TCAS report).**
- **Ambiguous Correlation**
  - **Multiple tracks found within TCAS report's gates and no address match exists between TCAS report and any of the track.**
- **No Correlation**
  - **No source-level track found within TCAS report's primary or secondary gates.**

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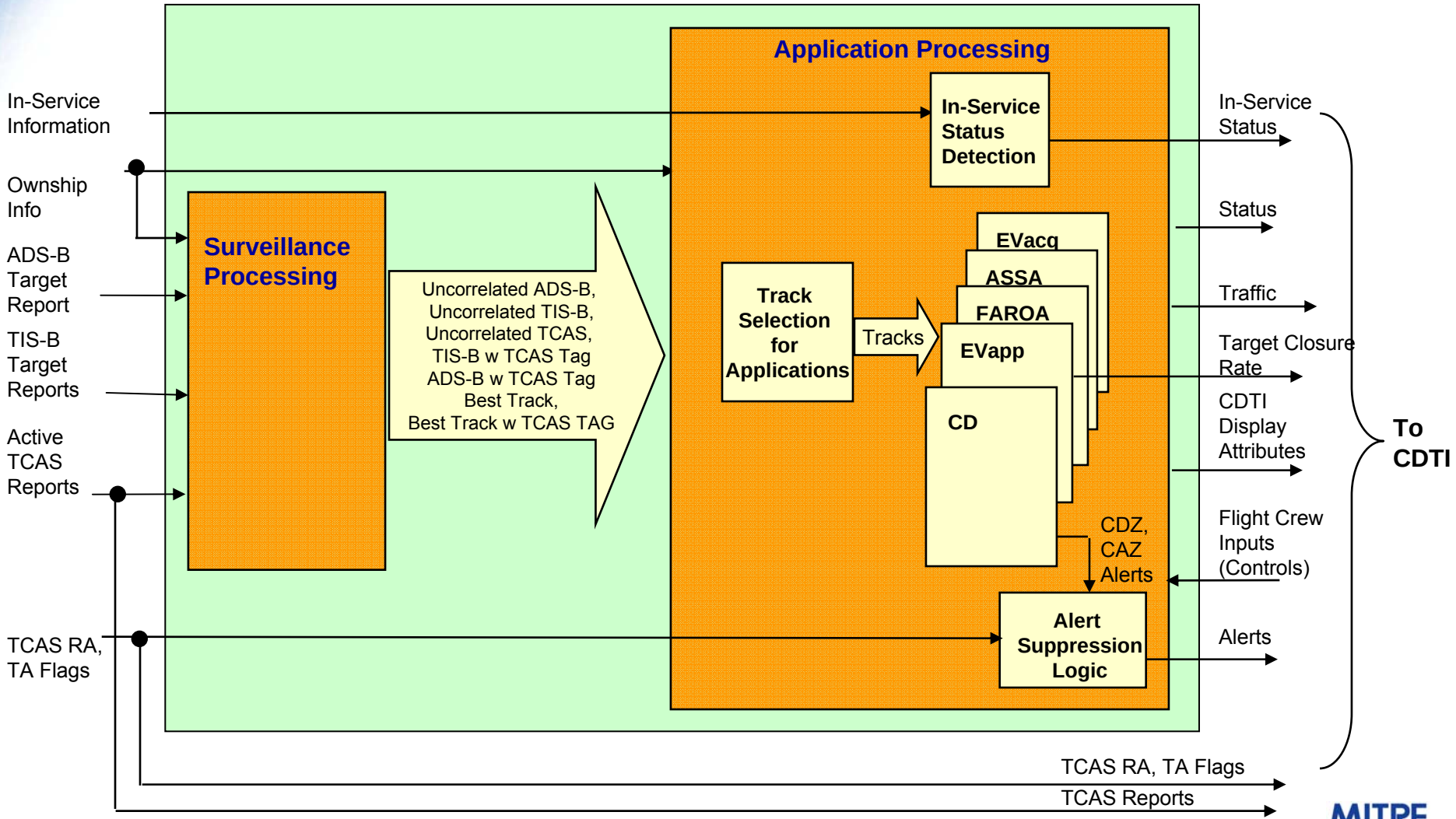
Best Source Selection

- **Best Track Selection is performed between TIS-B and ADS-B in cases where both are available.**
  - **For Fundamental Service TIS-B will normally provide for targets that are not ADS-B equipped and no ADS-B track will be available.**
    - **The exception is when ADS-B may not be detected on the ground but the air-to-air is detected in which case both can be available to the A/C simultaneously.**
- **When both ADS-B and TIS-B tracks are available on the same target, the best track selection *shall* be based on NIC followed by NAC.**
  - **See Joel's briefing for rationale.**

Proposed Application Processing - Basic Functions

- **Select tracks that are eligible for each active application (traced to the following ASA requirements):**
  - **R3.187: ASSAP *shall* make ASSAP track reports available to the CDTI for all active applications.**
  - **R3.195: ASSAP track quality *shall* be compared with acceptable values for basic and intermediate applications (Table 2-3).**
  - **R3.198: The ASSAP track report *shall* indicate if the track's quality is insufficient for a basic application.**
  - **R3.199: If the installed system has the option for CD, ASSAP *shall* determine if each track is eligible for CD processing, as per Table 2-3.**
- **Perform application processing (traced to R3.188-189, R3.190, R3.193-194, R3.197, R3.200-209).**
- **Detect if ownship is within a service volume (not traced to any ASA requirement).**
  - **An IN-Service Status report *shall* be provided to the CDTI.**
- **Provide CD suppression logic (not traced to any ASA requirements).**
  - **If TCAS data is to be integrated into the CDTI and CD application is an active application, CD alerts (CDZ and CAZ) *shall* be suppressed when TCAS alerts (TA or RA) are annunciated.**

Architectural Approach – Application Processing



Proposed ASSAP MOPS Requirements

ASSAP Sub-Function	Proposed MOPS Requirement	ASSAP MOPS Ref. #	ASA MASPS Trace #
Report-to-Track Association	The report-to-track association function *shall* pass spatial correlation.	x.1	R3.169, R3.170, R3.185
Report-to-Track Resolution	The report shall be resolved to update a track when a track falls within the validation region and its track ID matches the report ID.	x.2	R3.169, R3.170, R3.185
Report-to-Track Resolution	The report shall be resolved to initiate a new track when no track with a track ID that matched the report ID can be found within the validation gate.	x.3	R3.169, R3.170, R3.185 R3.177
Background Processing (TIS-B Merge)	*Option:* TIS-B Merge Function included: When a TIS-B track falls within the validation region of a TIS-B Report and there is no match between the track and report IDs, this correlation shall be noted as an update to the "M-out-of-N" pattern that the track keeps for that report. This correlation pattern is used by the Background Merge Function. (See Slide #xxx)	x.4	
Track Initiation	A new track *shall* be initiated when none of the existing tracks can be associated with the current Report.	x.5	R3.177
Track Initiation	The track *shall* be initiated after one report.	x.6	R3.177
Background Processing (Track Split)	The Background Processor *shall* search the track files (at a source level, i.e., for ADS-B/ADR-R and TIS-B tracks) to ensure that each track has a unique ID.	x.7	

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Proposed ASSAP MOPS Requirements

ASSAP Sub-Function	Proposed MOPS Requirement	ASSAP MOPS Ref. #	ASA MASPS Trace #
Background Processing (Track Split)	The criteria for splitting tracks with duplicate IDs into tracks with distinct track IDs shall be – Spatial Correlation: distance between the track positions > *Thr_distance* – Speed Inconsistency: difference in speed > *Thr_speed* – Ground Track Inconsistency (optional): difference in Ground Track > *Thr_GT*	x.8	
Background Processing (Track Split)	A new unique local track number shall be assigned to the track with the worse quality (based on NIC, then NAC). This track shall accept updates from reports of the previous ID #.	x.9	
Background Processing (Track Merge)	A sliding detection pattern (M detections out of the last N opportunities) shall be maintained between each track and reports (of different IDs) that have been spatially associated.	x.10	
Background Processing (Track Merge)	The track with the worst NAC shall be deleted when: • corresponding M/N patterns for both tracks exceeds a threshold (adaptable) • speed difference < threshold (adaptable) • Ground heading difference < threshold (adaptable)	x.11	
Background Processing (Track Merge)	After a merge has been determined, reports with both IDs shall be allowed to update the "merged" track.	x.12	
Background Processing (Track Termination)	The tracking function *shall* terminate a track when the maximum coast interval (Table 2-3, row 17) has been exceeded for all of the applications for which the track is potentially being used.	R3.178	R3.178

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Proposed ASSAP MOPS Requirements

ASSAP Sub-Function	Proposed MOPS Requirement	ASSAP MOPS Ref. #	ASA MASPS Trace #
Inter-Source Correlation (ADS-B/TIS-B)	Correlation between ADS-B and TIS-B tracks *shall* be established in the following order – Track ID is the same (unlikely to be the case). – Call Sign is the same (optional input). – Spatial correlation and velocity consistency is met over M-out-of-N most recent updates.	x.13	R3.172, R3.183, R3.184
Inter-Source Correlation (TCAS/ADS-B or TCAS/TIS-B)	Cross-referencing of tracks with TCAS reports *shall* be performed via spatial correlation with one or two gates: – Primary gate based on TCAS report's range and source type (i.e., TIS-B or ADS-B/ADS-R). – Secondary gate which is larger (adaptable) and provides a coarse correlation.	x.14	R3.172, R3.179, R3.181, R3.182
Inter-Source Correlation (Ownship/ TIS-B)	A TIS-B track that correlates with ownship shall be removed.	x.15	
Best Source Selection	When both ADS-B and TIS-B tracks are available on the same target, the best track selection shall be based on NIC followed by NAC.	x.16	

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Proposed ASSAP MOPS Requirements

ASSAP Sub-Function	Proposed MOPS Requirement	ASSAP MOPS Ref. #	ASA MASPS Trace #
Application Processing	An In-Service Status shall be provided to the CDTI.	x.18	
Application Processing	If TCAS data is to be integrated into the CDTI and the CD application is an active application, CD alerts (CDZ and CAZ) shall be suppressed when TCAS alerts (TA or RA) are annunciated.	x.19	

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ASA Requirements for ASSAP: Surveillance Processing, Application Processing, Performance, Input Interface, Output Interface

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ASA: ASSAP Requirements – Surveillance Processing

Sub-Function	ASA MASPS Ref. #	Requirement
ASSAP	R2.27	ASSAP ***shall*** assess the ability of own-ship and traffic targets to support the active applications or applications within an active ACL
Surveillance Processing	R3.169	ASSAP ***shall*** provide a tracking function.
	R3.170	The tracking function ***shall*** maintain, for each A/V under track, a file that contains, at a minimum, the elements listed in Table 3-4.
	R3.171	The tracking function ***shall*** determine all fields in Table 3-4 that are not directly provided in measurements. The last measurement data fields indicated in Table 3-4 are intended to include variables that were obtained with the last valid measurement received for the track.
	R3.172	The tracking function ***shall*** include a correlation function that associates traffic data from different surveillance sources that relate to the same a/v track, i.e., the correlation function is required to associate and cross-reference traffic data from ADS-B, TIS-B, and TCAS traffic.
	R3.173	The correlation function ***shall*** update traffic cross references when new information is available from the ADS-B/TIS-B receive subsystem or TCAS.
	R3.174	The tracking function ***shall*** include an estimation function that estimates track state based on one or more surveillance source inputs.
	R3.175	The tracking function ***shall*** optimize the quality of the track information best suited to the application being run (e.g., accuracy, integrity containment bound, or integrity containment risk).
	R3.176	The tracking function ***shall*** estimate the quality of the track state information that is maintained in the track file, and maintain quality measures for the track state information, as indicated in Table 3-15.

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ASA: ASSAP Requirements (cont'd) Surveillance Processing

Sub-Function	ASA MASPS Ref. #	Requirement
Surveillance Processing	R3.177	The tracking function ***shall*** initiate a tack for each observed a/v when sufficient measurement information is received to form a minimum track state.
	R3.178	The tracking function ***shall*** terminate a track when the maximum coast interval (Table 2-3, row 17) has been exceeded for all of the applications for which the track is potentially being used.
	R3.179	If TCAS data is to be integrated on the CDTI, ASSAP ***shall*** correlate the TCAS tracks with its internal tracks to the extent practicable.
	R3.180	For correlated TCAS tracks, ASSAP ***shall*** recognize if a track has an active TCAS resolution advisory or traffic advisory.
	R3.181	For correlated TCAS tracks, ASSAP ***shall*** provide that information in the track file (see Table 3-4).
	R3.182	The criterion for minimizing the probability of mismatching TCAS/ADS-B tracks, or not matching TCAS/ADS-B tracks ***shall*** be defined in the ASAS MOPS.
	R3.183	ASSAP surveillance processing ***shall*** cross-correlate the traffic from TIS-B and ADS-B reports supplied by the ADS-B receiver.
	R3.184	The criterion for minimizing the probability of mismatching TIS-B/ADS-B tracks, or not matching TIS-B/ADS-B tracks ***shall*** be defined in the ASAS MOPS.

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ASSAP Requirements (cont'd)
Surveillance / Application Processing

Sub-Function	ASA MASPS Ref. #	Requirement
Surveillance Processing	R3.185	If the aircraft ADS-B installations includes multiple ADS-B links, ASSAP surveillance processing ***shall*** correlate traffic from the different links and associate the traffic with the appropriate ASSAP track.
	R3.186	ASSAP ***shall*** provide current traffic state position information to the interface with the CDTI with at least a 1Hz rate.
	R3.200	ASSAP ***shall*** assess the TQL and ACL from all A/Vs to determine the ability of those A/Vs' equipment and broadcast data to support the installed applications.
Application Processing	R3.187	ASSAP ***shall*** make ASSAP track reports available to the CDTI for all active applications.
	R3.188	ASSAP ***shall*** deliver track reports to the CDTI for all aircraft of sufficient quality for at least enhanced visual acquisition, extrapolated to a common time that is within 1 second of the time the data is delivered to the CDTI, with at least a 1Hz rate.
	R2.189	ASSAP ***shall*** estimate the velocity accuracy, and use the estimated value to determine traffic qualification as appropriate as indicated by Table 2-3. (where there is no valid velocity data.)

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ASSAP Requirements (cont'd)
Application Processing

Sub-Function	ASA MASPS Ref. #	Requirement
Application Processing	R3.190	The horizontal position of the target track relative to own-ship ***shall*** be computed by applying the appropriate coordinate transformation between the track's latitude and longitude and own-ship's latitude and longitude and the display coordinates.
	R3.191	Supported application ***shall*** indicate the ASA Capability Level of the target track.
	R3.192	Supported application ***shall*** indicate any optional application that are being processed for the track (i.e., CD, ASSA, FAROA).
	R3.193	The degraded data field ***shall*** indicate if the data is considered to be degraded for an active application.
	R3.194	The selected target closure rate ***shall*** indicate the radial line of sight closure rate between own-ship and the selected target.
	R3.195	ASSAP track quality ***shall*** be compared with acceptable values for basic and intermediate applications (Table 2-3).
	R3.196	If the sole surveillance source of information is ADS-B or TIS-B, the track quality assessment ***shall*** be based on the TQL transmitted by the source and, for TQL >1, the NIC, NACp, NACv, and SIL requirements specified in Table 2-3.
	R3.197	The ASSAP track report ***shall*** be updated to reflect any degraded conditions for EVAcq or ASSA/FAROA, as appropriate, as per Table 2-3.
	R3.198	The ASSAP track report ***shall*** indicate if the track's quality is insufficient for a basic application.

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ASSAP Requirements (cont'd)
Application Processing

Sub-Function	ASA MASPS Ref. #	Requirement
Application Processing	R3.198	The ASSAP track report ***shall*** indicate if the track's quality is insufficient for a basic application.
	R3.199	If the installed system has the option for CD, ASSAP ***shall*** determine if each track is eligible for CD processing, as per Table 2-3.
	R3.200	Each track that is eligible for CD ***shall*** be process by the CD alerting function.
	R3.201	CAZ alerts or CDZ alerts ***shall*** be issued as appropriate.
	R3.202	ASSAP ***shall*** include in the ASSAP track report the status of the CAZ alert and the CDZ alert.
	R3.203	The ASA MASPS version number ***shall*** be used to coordinate applications processing appropriately for the version combination on own-ship and the target ship.
	R3.204	Call Sign/Flight ID ***shall*** be included in the ASSAP track file.
	R3.205	Call Sign/Flight ID ***shall*** be included provided to the CDTI in the ASSAP/CDTI report.
	R3.206	ASA Category ***shall*** be forwarded to the CDTI.
	R3.207	A/V length and width codes ***shall*** be forwarded to the CDTI.
	R3.208	Emergency/priority status ***shall*** be forwarded to the CDTI.
	R3.209	ASSAP convert heading from true or magnetic heading to the appropriate orientation for consistent display on the CDTI.

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ASSAP Requirements (cont'd) Performance

Sub-Function	ASA MASPS Ref. #	Requirement
Performance Requirements	R3.210	Latency for the combination of ASSAP and CDTI ***shall*** be less than 400 ms for targets that are used by coupled applications, targets against which there is an alert, and the 10 highest priority targets.
	R3.211	For all other targets, data latency ***shall*** be less be less than 1 second.. (The prioritization of targets is application-specific and is to be specified in the ASAS MOPS. The specific allocation of latency to ASSAP and CDTI is also to be specified in the MOPS, including bus latencies.)
	R3.212	ASSAP ***shall*** achieve the subsystem integrity risk and continuity risk requirements listed in Table 3-17.
Input Interface Requirements	R3.213	All data indicated by a dot in Table 3-18 ***shall*** be provided to the ASSAP function. All data indicated by the letter "d" are optional, desired interfaces.
	R3.314	For initial ASA applications, TCAS data is needed to support configurations with integrated ASA/TCAS traffic displays. The data items in 3.3.2.3.2 ***shall*** be provided to ASSAP for each TCAS track that is to be displayed.
	R3.315	ASSAP ***shall*** accept a Resolution Advisory flag from the TCAS equipment.
	R3.316	ASSAP ***shall*** accept a Traffic Advisory flag from the TCAS equipment.
	R3.317	?? check with latest STP requirement on ownship quality requirement.

ASA: Output Interface Requirements for Basic and Intermediate Applications

	ASA-MASPS Section References	Features	Applications			
			EV Acq.	CD	FAROA, ASSA	EV App.
Display Elements	3.3.3.1.1.1	Display Range /Map Scale	R	R	R	R
	3.3.3.1.1.1.1	Reduced Display Range			R	
	3.3.3.1.1.1.2	Extended Display Range				
	3.3.3.1.1.1.3	Range / Map Scale Ref.	R	R	R	R
	3.3.3.1.1.2	Display Orientation	R	R	D	R
	3.3.3.1.1.3	Application-Specific Display Features				
	3.3.3.1.1.3.1	Airport Surface Map			R	
	3.3.3.1.1.3.2	Extended Runway Center Line and Final Approach Course			R	
	3.3.3.1.1.3.3	ANDS Indication		R		
	3.3.3.1.1.3.4	Low Level Alert disabled		R		
	3.3.3.1.1.3.5	Recommended Speed				

R = Required; D = Desired
Source: DO-289 Table 3-19

Output Interface Requirements (cont'd)

Symbols	3.3.3.1.2.1	Own-Ship Symbol	R	R	R	R
	3.3.3.1.2.2	Traffic Symbols – basic requirements	R	R	R	R
	3.3.3.1.2.3	Traffic Symbols - variations	R	R	R	R
	3.3.3.1.2.4	Selected Target	D	D	D	R
	3.3.3.1.2.5	Coupled Target				
	3.3.3.1.2.6	Traffic Information Quality	R	R	R	R
Misc.	3.3.3.1.3.1	Traffic Display Criteria	R	R	R	R
	3.3.3.1.3.2	Loss of Own-Ship Directionality	R	R	R	R
Traffic	3.3.3.1.4.1	Time of Applicability	R	R	R	R
	3.3.3.1.4.2	Traffic ID (Call Sign / Flight ID)		D	D	R
	3.3.3.1.4.3	Traffic Category	D	D	D	D
	3.3.3.1.4.4	Traffic Length / Width Codes			R	
	3.3.3.1.4.5	Traffic Horizontal Position	R	R	R	R
	3.3.3.1.4.6	Traffic Air / Ground Status	R	R	R	R
	3.3.3.1.4.7	Traffic Altitude (Relative or Actual)	R	R	R	R
	3.3.3.1.4.8	Traffic Vertical Rate Indicator	R	R	R	R
	3.3.3.1.4.9	Traffic Horizontal Velocity Vector		D		R
	3.3.3.1.4.10	Traffic Heading			R	

R = Required; D = Desired
Source: DO-289 Table 3-19

Output Interface Requirements

Selected Target	3.3.3.1.5.1	Selected Target Highlighting	D	D	D	R
	3.3.3.1.5.2	Selected Target ID	D	D	D	R
	3.3.3.1.5.3	Selected Target Category	D	D	D	R
	3.3.3.1.5.4	Selected Target Ground Speed	D	D	D	R
	3.3.3.1.5.5	Selected Target Range	D	D	D	R
	3.3.3.1.5.6	Selected Target Closure Rate	D	D	D	R
	3.3.3.1.5.7	Off-Display Selected Target Bearing	D	D	D	R
Alerting	3.3.3.1.6.1	Alerted Traffic Symbol		R		D
	3.3.3.1.6.2	Off-Display alerted Traffic Bearing Indicator		R		D
	3.3.3.1.6.3	Application Alerts		R		D

R = Required; D = Desired
Source: DO-289 Table 3-19

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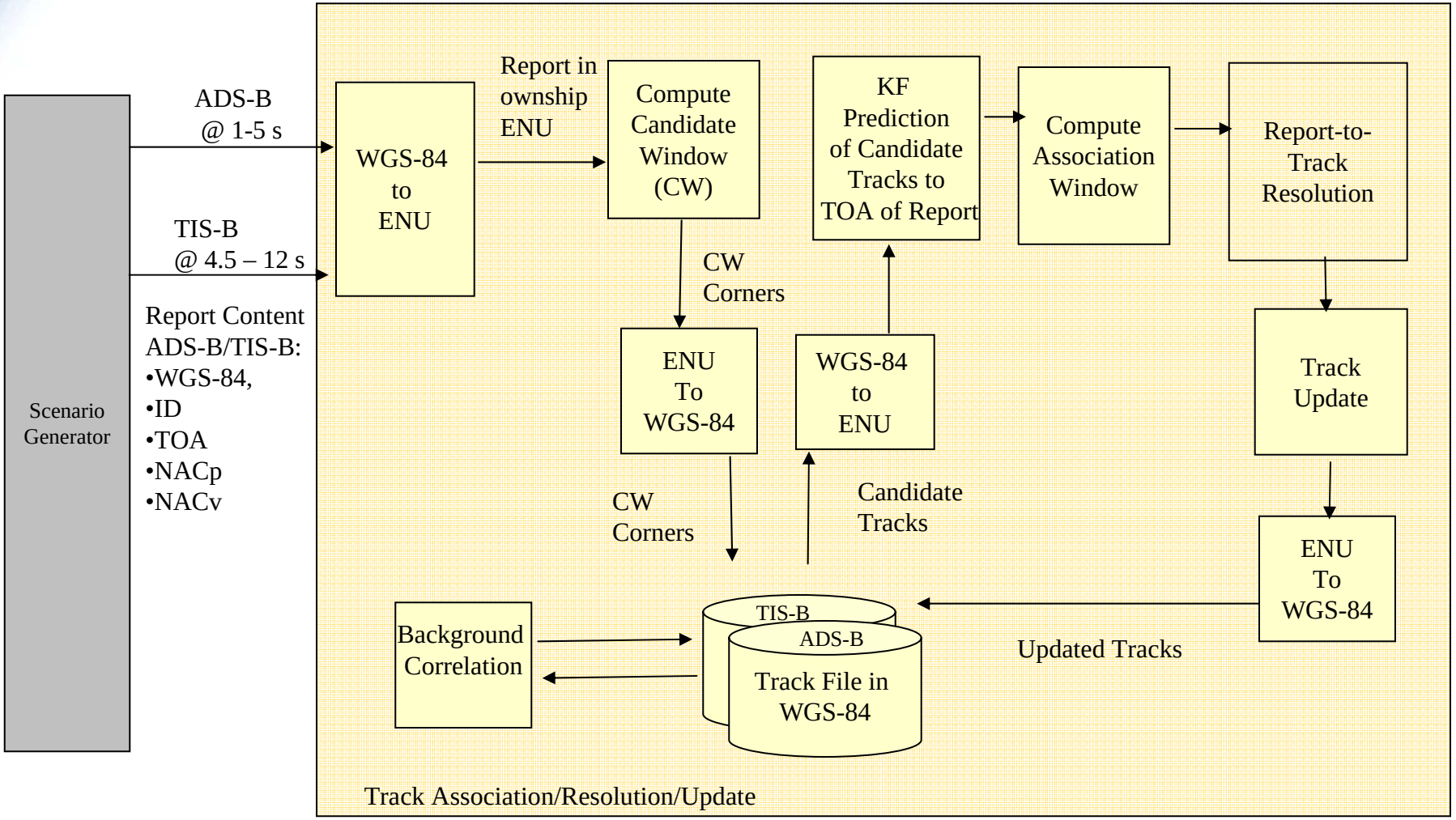
ASSAP Implementation

Process of Track Association/Update for each Track Type



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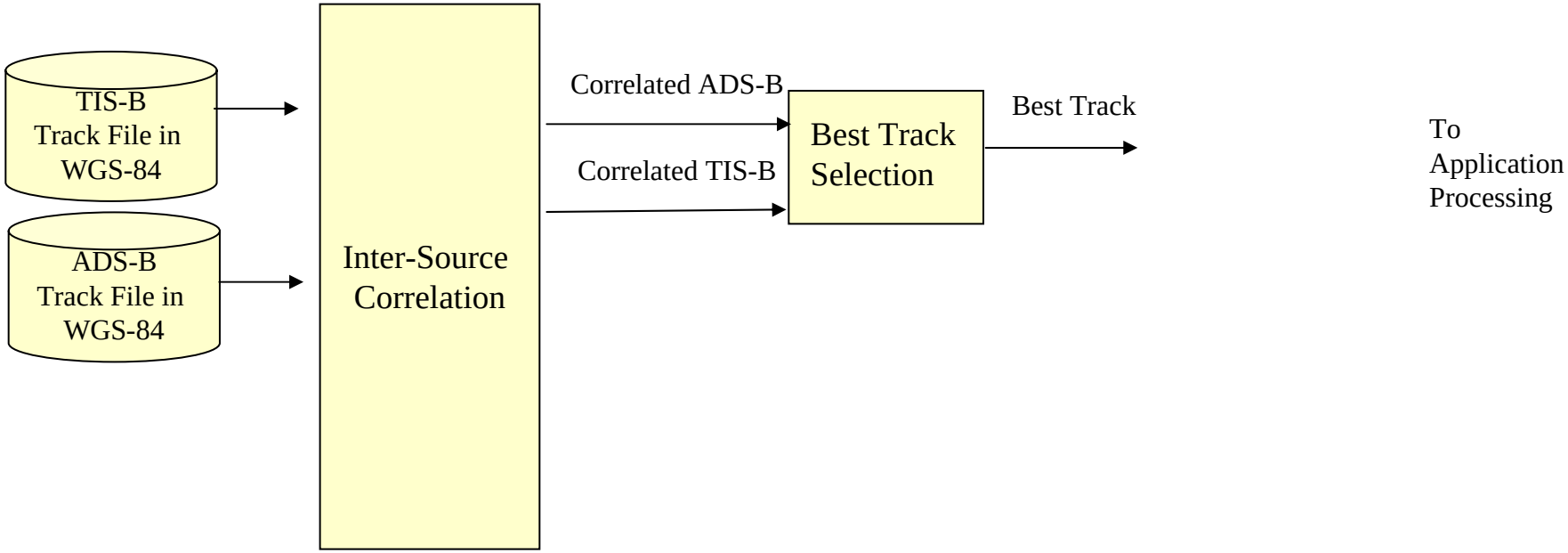
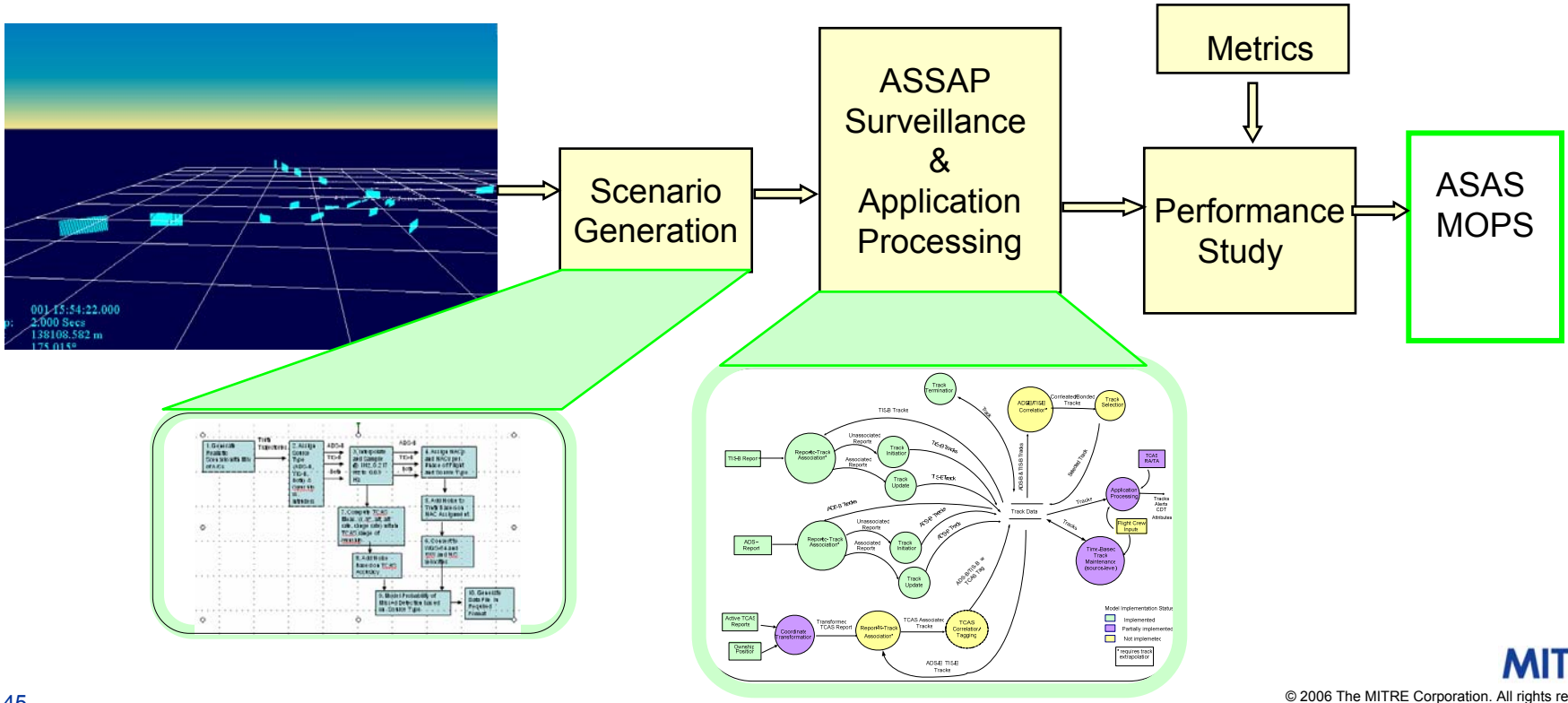
ADS-B to TIS-B Track-to-Track Correlation, Best Track Selection, and Application Track Selection



Approach to MOPS Specifications

- **Build simulation of ASSAP. Architectural approach:**
  - **Implement Distributed Tracking, Best-Of Track Selection, TCAS Tagging.**
- **Define and develop realistic scenarios.**
  - **Start with TASF scenarios as truth trajectories, simulate ADS-B, TIS-B, TCAS**
- **Use simulation results to develop MOPS level requirements.**
  - **Define metrics, Conduct Performance Study, Develop Requirements.**



Report-to-Track Association – Association Window

- **For each report, compute a report-to-track *Association Window* (AW) centered on the report, i.e., for every track that falls inside the CW. The size of the AW is calculated from the track uncertainty, measurement uncertainty and potentially an additional lag:**

$$x_{window} = \pm\left(3 * \sqrt{P_{\varepsilon_{xx}}} + \Lambda_x\right)$$
$$y_{window} = \pm\left(3 * \sqrt{P_{\varepsilon_{yy}}} + \Lambda_y\right)$$
$$z_{window} = \pm\left(3 * \sqrt{P_{\varepsilon_{zz}}} + \Lambda_z\right)$$

  - **$P\varepsilon_{xx}$, $P\varepsilon_{yy}$ are covariances of the residual vector between the measurement and predicted track position.**

$$\boldsymbol{P}_{\boldsymbol{\varepsilon}_{xx}} = \boldsymbol{P}_{\boldsymbol{M}_{xx}} + \boldsymbol{P}_{\boldsymbol{P}_{xx}}$$
$$\boldsymbol{P}_{\boldsymbol{\varepsilon}_{yy}} = \boldsymbol{P}_{\boldsymbol{M}_{yy}} + \boldsymbol{P}_{\boldsymbol{P}_{yy}}$$
$$\boldsymbol{P}_{\boldsymbol{M}_{xx}}, \boldsymbol{P}_{\boldsymbol{M}_{yy}} \text{ are measurement variances } \left(\mathrm{NAC}_{\mathrm{p}}^{2}\right)$$
$$\boldsymbol{P}_{\boldsymbol{P}_{xx}}, \boldsymbol{P}_{\boldsymbol{P}_{yy}} \text{ are predicted track variances}$$

  - **Λ_x, Λ_y, predicted lags for the track at the time of the measurement.**
- **Predict the position of all the tracks inside the CW to the time of the report.**
  - **Convert the tracks from WGS-84 to ENU.**
  - **Predict its trajectory assuming straight line motion.**
- **Determine if the predicted position of the track - found in the CW and used to compute the AW – in addition falls inside the AW for that report-to-track pair.**
  - **If the predicted track falls inside the AW, set a "1" in the *track.SamePattern* (M/N pattern) for that track (see later slide)**
  - **Else set a "0" in the *track.SamePattern* for that track.**
- **For all tracks except track with the same ID as the report that fall outside the CW.**
  - **If there is no field for that report in the structure for that track, create a new field and set the *track.SamePattern* to "0".**
  - **Else, update the *track.SameCorrPattern* by adding a "0" to the end of the pattern.**

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