WG-6 Intent Proposal for Revision A ADS-B MASPS

- Summary of Intent Proposal
- Short Term and Long Term Intent
- Target State Reports (TSR's)
- Trajectory Change Point Definition and TCP Type
- Trajectory Change Reports (TCR's)
- Minimum Intent Report Requirements

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Potential Uses of ADS-B Intent

- Extended Trajectory Prediction
- Provide Limiting Conditions for Flight Segment Extrapolation
  - Distance, time and altitude limits for trajectory prediction
- Signal Changes in Current Intent, e.g. Intended Climb / Descent
- Applications
  - ASAS Separation Planning and Conflict Resolution
  - Ground Based Flow Sequencing and Arrival Merging
  - ATC Clearance Verification and Conformance Monitoring
  - Precision Trajectory Separation in Congested Airspace

DO-242 MASPS Intent Issues

- DO-242 MASPS Intent Integrity Issues:
  - TCP format does not define a path to the TCP
  - TCP format does not specify intended trajectory change
  - Inadequate Information to Assess Confidence in Broadcast Intent
  - TCP format should reflect path constraints, e.g. At or Above/Below constraints
- ADS-B Intent Should Reflect Aircraft Capabilities:
  - Autopilot, FMS and RNAV automation capabilities
  - Mixed autopilot/FMS Modes, e.g.
    - Heading Intercept of LNAV Path
    - VNAV Descent to Intermediate Target Altitude
- Intent Expansion Desired for Longer Lookahead and More Complex Trajectories, e.g. 4 TCP's

Additional Justification for Intent Proposal

- International Coordination of Intent Introduction
  - Target Altitude Harmonized with European Intent Plans
  - Introduction of Multiple TCP's to Support Air-Ground Applications
- Rev A MASPS Enhancements Encourage Early Intent Implementations
  - Minimizes Impacts to Initially Fielded ADS-B Equipment
  - Early Test and Evaluation of Intent Data Structures

Intent Proposal Implementation Strategy

- Aircraft Avionics Today Provide Only Limited Intent Data
  - Avionics Buses May Provide Some Intent Today, e.g. Selected Altitude and Heading, Intent Bus (ARINC 702A-1)
  - Most FMS Systems do not Provide Intent Information in a Usable Form
    - Most Intent is Internal to Guidance, Control and Display Functions
    - Few, if any FMS systems support comprehensive output buses
- Proposal Provides Incremental Approach to ADS-B Intent
  - Enables Partial Intent Broadcasting for Near Term Implementations
  - Evolution to more Comprehensive Intent
    - Intent Data Formats Provide Future Growth Capability
    - Provisioning Capability for Aircraft Avionics Upgrades

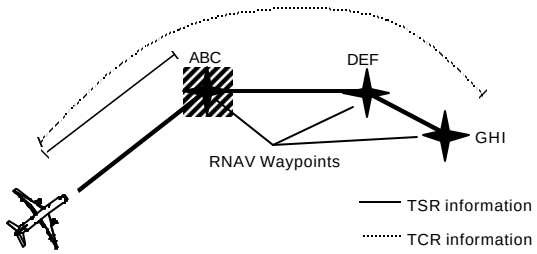
WG-6 Intent Proposal Summary

- Introduces Target State Reports (TSR's)
  - Target Altitude: Current or Next Level-Off Altitude
  - Target Heading / Track: Current Target Direction
  - Includes Altitude Capability, Source and Mode Indicators
- Modified TCP Definition: Includes 4D Waypoints and Generic Change Points
- New Trajectory Change Reports (TCR's)
  - Includes flight segment parameters and endpoint TCP's
  - Up to four TCP's ordered by Time to Go (TTG)
  - Includes TCP type and Distinguishes between Command and Planned flight segments
  - Provisions Altitude Constraints, e.g. AT, AT or Above/Below

WG-6 Recommendations for Intent Introduction

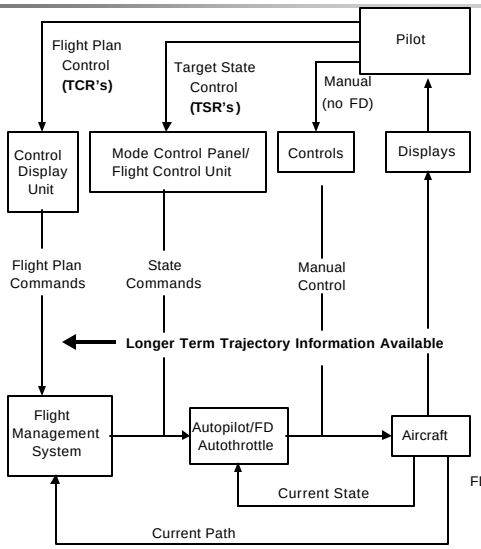
- Proposal for Modified DO-242 Equipage Levels
  - A0 = Basic State Vector Broadcast Capability
    - ➢ Position, velocity, identity
  - A1 = A0 plus TSR (target altitude and target heading / track)
  - A2 = A1 plus a single TCR
  - A3 = A2 plus Enhanced Range Intent: Up to 4 TCP's
- Impact on ADS-B MOPS
  - Level A1 Intent Capability Proposed for all ADS-B MOPS
  - Level A2 Intent MOPS Introduction (if feasible)
  - Growth to Level A3 Intent – TCR Data Format Supported
- Intent Data Structures Provide Growth for Future Applications
  - Provide Vision for Airborne Architecture Evolution
  - Enable Test and Evaluation of Advanced ADS-B Systems

Short Term and Long Term Intent Information Provided in TSR and TCR



- Example shows information provided in TSR and TCR for a simple trajectory with area navigation (RNAV) waypoints.
- TSR provides information on current flight segment (target altitude and target track to ABC).
- TCR gives location of ABC, DEF, and GHI waypoints and connecting flight segments.

Aircraft Control States



FD: Flight Director

- ✓ Control state and aircraft equipage affect amount of intent information available.
- ✓ With each additional outer loop, more intent information is available for broadcast.
  - ➢ Manual - no intent.
  - ➢ Target state - TSR.
  - ➢ Flight Plan - TCR.
- ✓ TSR and TCR take advantage of intent available in simple or complex control states.

Target State Report – Data Structure

Element #	Contents	
4	Data Available (Vertical)	
5	Target Altitude[1]	
6	Target Altitude Capability	
7	Target Source Indicator (Vertical)	
8	Mode Indicator (Vertical)	
9	(Reserved for Vertical Conformance)	
	(Reserved for future growth)	
10	Data Available (Horizontal)	
11	Target Heading / Track[2]	
12	Heading / Track Indicator	
13	Target Source Indicator (Horizontal)	
14	Mode Indicator (Horizontal)	
15	(Reserved for Horizontal Conformance)	
	(Reserved for future growth)	

[1] Selected Altitude May Be Provided as a Substitute for Target Altitude
[2] Target Heading / Track to be Broadcast if Available

Trajectory Change Point (TCP) Basics
(DO-242 Intent Capability)

- "The TCP from the transmitting aircraft is the point in three dimension space where the current operational trajectory is planned to change, and estimated remaining flight time to that point." – DO-242, pg. 39

- Trajectory Change Point (TCP) Characteristics
  - Basic TCP consists of a 2-D latitude & longitude and a Baro-Altitude/Flight Level
  - Estimated Time to TCP (TTG) is specified when available
  - Changes in routing (horizontal path and vertical path) are specified via TCP's:

TCP Change Point Definition and TCP Type

- Revised TCP definition accommodates change points not defined by precise 4D location, such as conditional waypoints affected by wind and aircraft performance.
  - Proposed new TCP definition:
    - "A Trajectory Change Point may be described as a 3D location or interception of a 2D plane with the aircraft's velocity vector where the current aircraft trajectory is intended to change."
  - TCP type in TCR interprets horizontal and vertical segment "leg" type and TCP change type:
    - Allows receiving systems to reconstruct flight segments and to assess TCP location uncertainty.
    - Describes aircraft transition at TCP.

Trajectory Change Report - Data Format

Element #	Contents	MASPS Version
4	TCRsequence number	Rev A
5	TCR Cycle number	Rev A
6	Time to Go (TTG)	DO-242
7	Data Available (Horizontal)	Rev A
8	TCP Type (Horizontal)	Rev A
9a	Latitude	DO-242
9b	Longitude	DO-242
10	Turn Radius	Rev A
11	Track to TCP	Rev A
12	Track from TCP	Rev A
13	(Reserved for Horizontal Conformance)	Growth
14	Command/Planned (Horizontal)	Rev A
15	Data Available (Vertical)	Rev A
16	TCP Type (Vertical)	Rev A
17	Altitude	DO-242
18	(Reserved for Altitude Constraint Type)	Growth
19	(Reserved for Able/Unable Altitude Constraint)	Growth
20	(Reserved for Vertical Conformance)	Growth
21	Command / Planned (Vertical)	Rev A

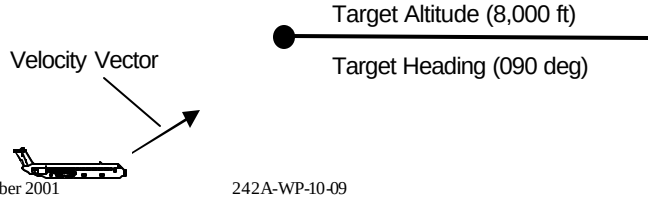
Minimum Intent Reporting Requirements

- Issues with Current TCP Report Requirements
  - DO-242 TCP Req'ts are Implicit, e.g. Based on Time to CPA
  - Report Rate Should be Lower for Remote TCP's, e.g. large TTG
  - Most Intent Data is Highly Redundant, i.e. need to reduce over-broadcast of redundant data
- Proposed TCR Reporting Requirements
  - High Data Rate Reporting only for TCR's with TTG < threshold
    - Recommend 2.5 min threshold and 10 sec updates with 95% prob.
  - Low Data Rate Reporting for TCR's with TTG > threshold
    - At least one update between 5 min TTG and 2.5 min threshold
  - No TCR+n Reporting required for n>0 and TTG > 20 min

Presentation Backup Slides

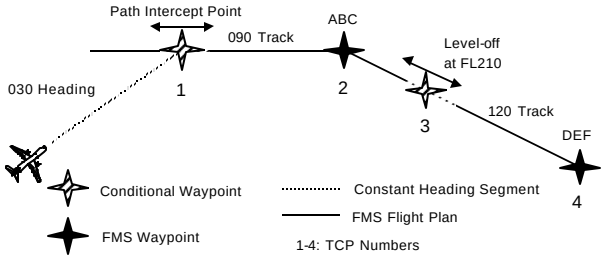
Target State Report and Example

- Target State Report (Primary Elements with *Example Values in Italics*):
  - Target altitude - next level-off altitude or intended holding altitude if in level flight (*8,000 ft).*
  - Target heading/track - commanded direction (*target heading 090 degrees*).
  - Mode indicator - acquiring or capturing/maintaining target (*Horizontal - maintaining, Vertical - acquiring*).
  - Target source indicator - autoflight system source or current state that drives guidance function (*Horizontal – MCP Selected heading, Vertical – MCP Selected altitude*).



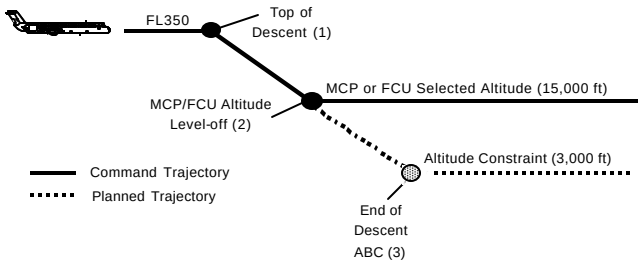
Example with Various TCP Types

- Aircraft flies 030 heading to join FMS path at TCP #1, while climbing to FL210. Aircraft levels off at TCP #3.
- TCP's:
  - TCP #1, 030 Heading Intercept of FMS Path
  - TCP #2, Fly-By Turn at Waypoint ABC
  - TCP #3, Target Altitude Level-off at FL210
  - TCP #4, Fly-By Turn at Waypoint DEF

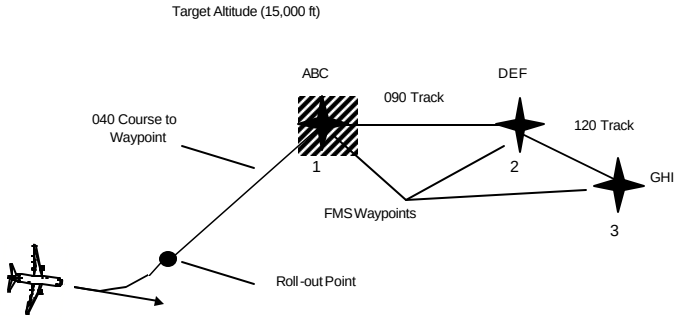


Command and Planned Trajectories

- TCR provides distinction between intent states that are actual targets for the autoflight system (command trajectory) and those that merely represent a pilot's plan or preference (planned trajectory). Example:
  - Command Trajectory: Aircraft flies to top of descent, descends along vertical path until reaching intermediate MCP altitude limit.
  - Planned Trajectory: Vertical FMS path below limiting MCP altitude (includes End of Descent point).



Trajectory Change Report Example: Intercept Course to FMS Flight Plan



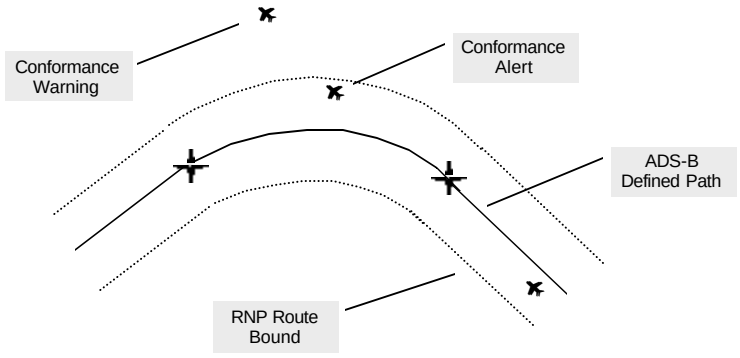
Trajectory Change Report Elements – Example Format

Element #	Contents	TCR Values	TCR+1 Values	TCR+2 Values
4	TCR sequence number	0	1	2
5	TCR Cycle number	1	1	1
6	Time to Go (TTG)	TTG-ABC	TTG-DEF	TTG-GHI
7	Data Available (Horiz)	Available	Available	Available
8	TCP Type (Horiz)	CF and Fly-By	TF and Fly-By	TF and Fly-By
9a	Latitude	Latitude ABC	Latitude DEF	Latitude GHI
9b	Longitude	Longitude ABC	Longitude DEF	Longitude GHI
10	Turn Radius	Radius ABC	Radius DEF	Radius GHI
11	Track to TCP	040 deg	090 deg	120 deg
12	Track from TCP	90 deg	120 deg	Track from GHI
14	Command/Planned-H	Command	Command	Command
15	Data Available (Vert)	Available	Available	Available
16	TCP Type (Vertical)	Target Altitude	Target Altitude	Target Altitude
17	Altitude	15,000 ft	15,000 ft	15,000 ft
21	Command/Planned-V	Command	Command	Command

Trajectory Change Report – Provisioning for Future

- Vertical Altitude Constraints (At, At or Above / Below)
  - Three bits reserved for altitude constraint indicator and "able / unable" altitude constraint flag
- Horizontal and Vertical Trajectory Conformance
  - Two bits reserved for horizontal and vertical path conformance, e.g. "able / unable" RNP path containment
  - Additional elements may be required for user intent containment assessment, e.g. RNP-0.3 lateral containment

Trajectory Conformance Monitoring Example
(ADS-B User/Receive Side Integrity Monitoring)



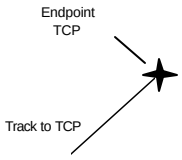
Note: May require transmission of current RNP capability

Horizontal TCP Types for Revision A MASPS

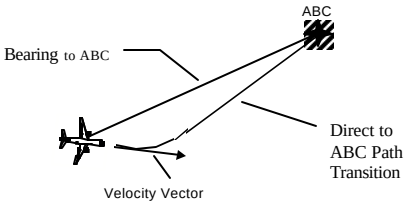
- Horizontal TCP Types Incorporate Straight Course and Lateral Turn Transitions (Fly-By, Fly-Over, Radius to Fix):

  0 = Direct-to Fix Lateral Transition (DF leg type)
  1 = Geodesic Path (Straight Course) to Fix Lateral Transition (CF and TF leg types)
  2 = Fly-By Turn Transition (CF or TF to Fly-By turn)
  3 = Direct to Fly-By Turn Transition (DF to Fly-By)
  4 = Radius to Fix Turn Transition (RF turn)

Straight Course and Direct-to-Fix Transitions

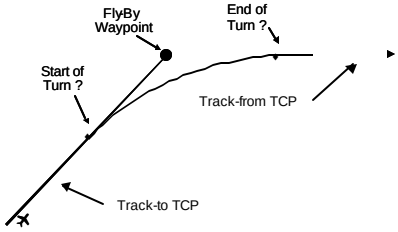


Geodesic Path (Straight Course) to Fix Lateral Transition

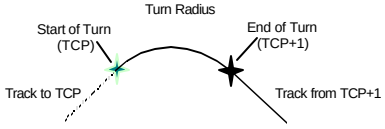


Direct to ABC Lateral Transition

Course to Fly-By and Radius to Fix Lateral Transitions



Course to Fly-By Turn Transition



Course to Fix / Radius to Fix Turn Example

Vertical TCP Types for Revision A MASPS

0 = Unknown Altitude Type

1 = Target Altitude

2 = Constraint Altitude (provisioning in Rev A)

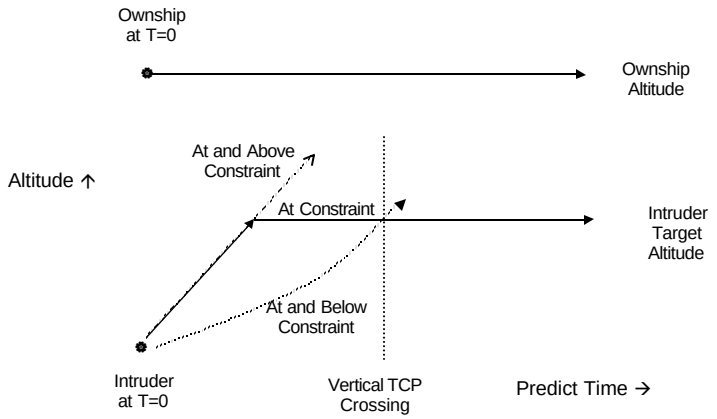
3 = Estimated Altitude

4 = Top of Climb (TOC)

5 = Top of Descent (TOD)

Target Vertical Prediction Issue – Rev A

(Illustrates Need for Altitude Constraint Broadcast)



TCR Report Synchronization and Refresh Req'ts

- Problem: How to Assure that all TCR's are current and valid, and have the correct TCR sequence number ?
- Proposed Solution:
  - TCR Cycle number (0,1,2,3) is incremented each time TCR sequence changes or one or more TCR's are invalid
  - TCR Cycle number is reported in Mode Status Report and in TCR Report to Purge out-of-date TCR's
  - TCR+0 is Purged and TCR Sequence numbers are decremented when TCP or segment endpoint is reached
  - TCR 'refresh' occurs when no new TCR data is received, i.e. time of applicability, TTG and coast time are updated