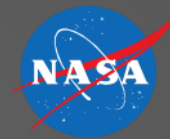


# MACS ATC Overview

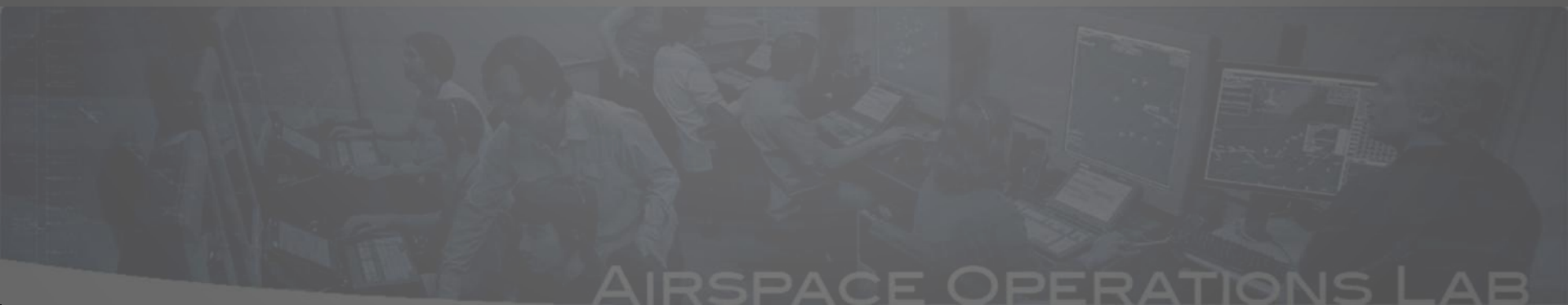
Tom Prevot, Connie Brasil, Michael Kupfer,  
Joey Mercer

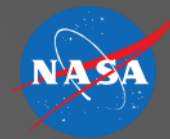




# Overview

- Terminal area controller stations
- Enroute controller stations in the near- and mid-term
- Traffic flow and airspace management stations
- Automated enroute controller stations in the far-term





Multi Aircraft Control System (MACS)

# TERMINAL AREA CONTROLLER STATIONS

Arriving aircraft pass through feeder and final sectors. Today there is little to no automation support and all communication is voice. MACS provides some advanced capabilities.

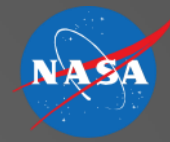
Video shows a Controller Managed Spacing simulation



# Terminal Area Air Traffic Control



# ATC in the Terminal Area

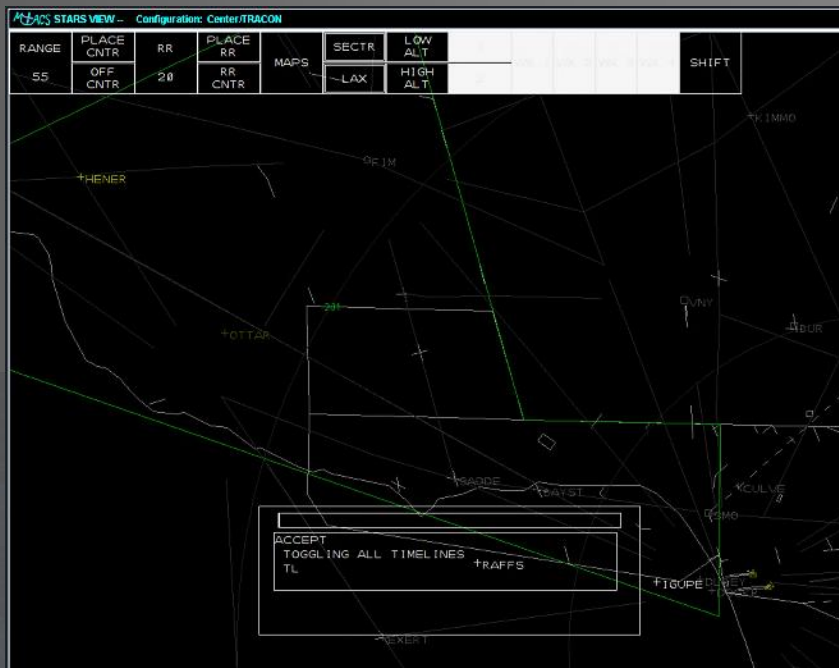


Operator-Mode:  
TRACON-Controller



Primary Display:  
STARS View

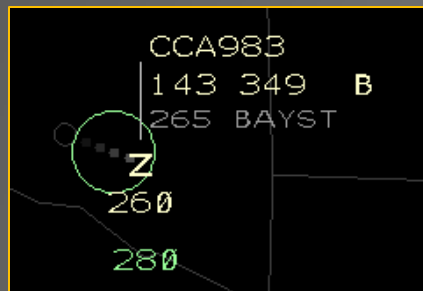
STARS: Standard Terminal Automation Replacement System



## Most Relevant Setup Files:

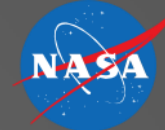
- ATC DST Configuration
- ATC DST Sector Configuration
- STARS Data Tag Rules Setup
- STARS Plan View Setup
- STARS Sector Plan View Setup
- STARS Timeline Setup
- Scheduler Setup

# Advanced Terminal Area Tools



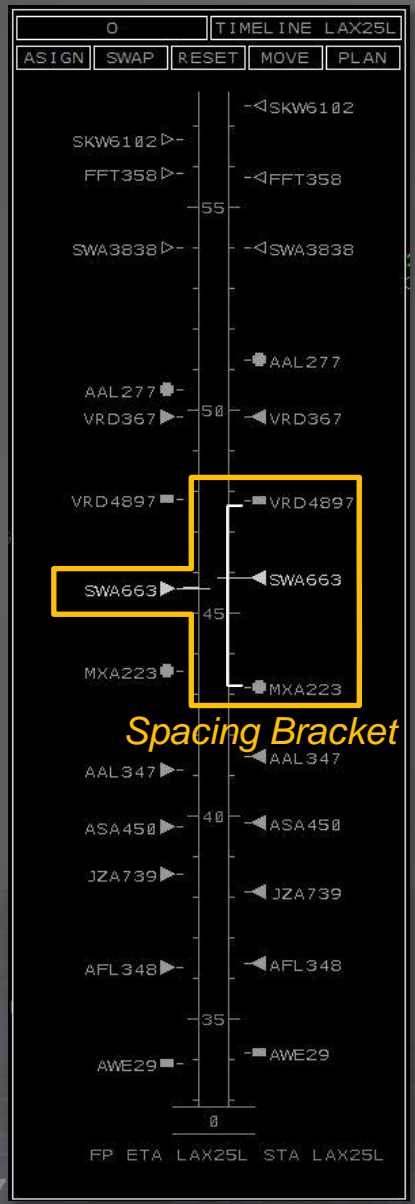
- Simple Scheduling Capabilities
- Controller Managed Spacing Tools
  - Slot Markers
  - Timelines
  - Speed Advisories
- ATC procedures
- CTAS TMA Integration





# Controller Support for Managing OPDs

Three Successively More Advanced Toolsets



"Timeline"



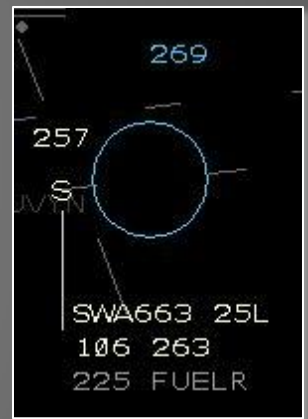
Early/Late Indication

"Slot Marker"



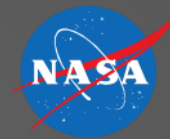
Early/Late Indication + Slot Marker

"Speed Advisory"



Slot Marker + Speed Advisory

- Display elements available in all conditions:
- Timeline with dwell-able required spacing brackets
  - Airspeed next to aircraft target
  - J-rings, route display, LA spacing ('splat')
  - Terminal proximity alert spacing cones ('bats')



Multi Aircraft Control System (MACS)

# EN ROUTE ATC OPERATIONS NEAR-TERM / 2016

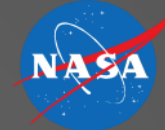
18 aircraft are allowed in Airspace “sectors” at any given time  
Teams of 2 Air Traffic Controllers per sector required for high traffic  
Video shows 8 controllers handling ~75 aircraft





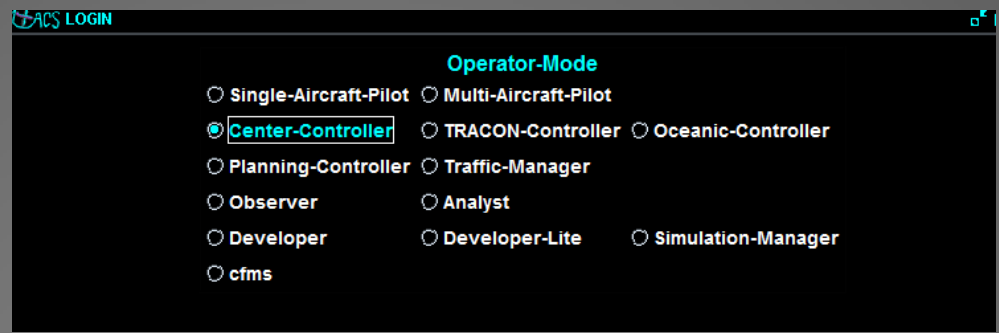
# Air Traffic Control





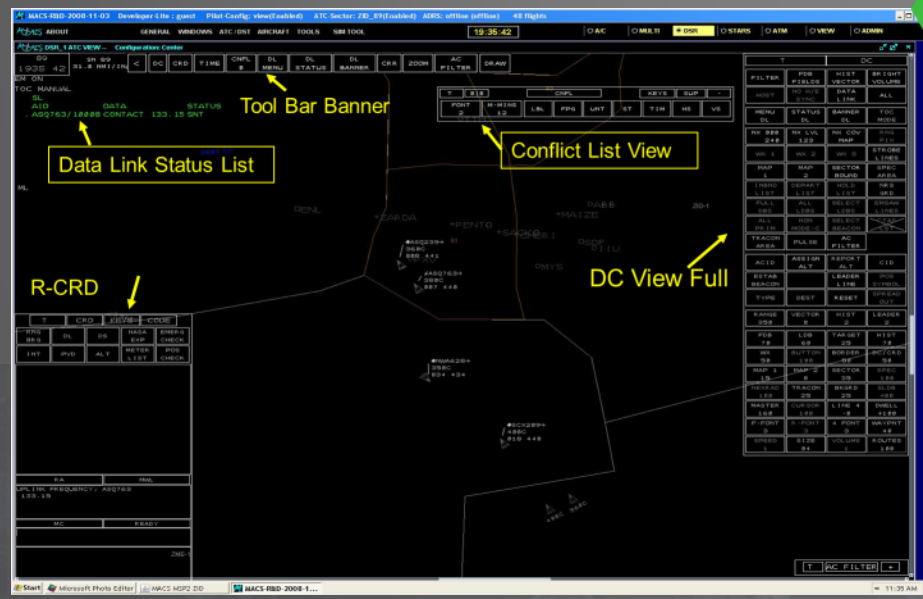
# En Route Controller Positions

## Operator-Mode: Center-Controller



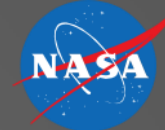
## Primary Display: DSR View

DSR: Display System Replacement



## Most Relevant Setup Files:

- ATC DST Configuration
- ATC DST Sector Configuration
- DSR Data Tag Rules Setup
- DSR Plan View Setup
- DSR Sector Plan View Setup
- DSR Timeline Setup



# En-Route: R-side & D-side DSR

MACS R&D-2008-11-03 Developer-Lite : guest Pilot-Config: view(Enabled) ATC Sector: ZID\_B9(Enabled) ADRS: offline (offline) 48 flights

MACS ABOUT GENERAL WINDOWS ATC/DST AIRCRAFT TOOLS SIM TOOL 19:35:42 A/C MULTI DSR STARS ATM VIEW ADMIN

MACS DSR\_1 ATC VIEW -- Configuration: Center

89 SN 89 1935 42 31.0 NMI/IN. < DC CRD TIME CNFL 0 DL MENU DL STATUS DL BANNER CRR ZOOM AC FILTER DRAW

EM ON TOC MANUAL SL AID DATA STATUS ASQ763/10008 CONTACT 133.15 SNT

**Tool Bar Banner**

**Data Link Status List**

**Conflict List View**

**R-CRD**

**DC View Full**

T		DC	
FILTER	FDB FIELDS	HIST VECTOR	BRIGHT VOLUME
HOST	NO H/E SYNC	DATA LINK	ALL
MENU DL	STATUS DL	BANNER DL	TOC MODE
NX 000 240	NX LVL 120	NX COV MAP	RNG FIX
WX 1	WX 2	WX 3	STROBE LINES
MAP 1	MAP 2	SECTOR BOUND	SPEC AREA
INBND LIST	DEPART LIST	HOLD LIST	NRS GRD
FULL DBS	ALL LDBS	SELECT LDBS	EMSAW LINES
ALL PRIM	NON MODE-C	SELECT BEACON	CTAS LST
TRACON AREA	PULSE	AC FILTER	
ACID	ASSIGN ALT	REPORT ALT	CID
ESTAB BEACON		LEADER LINE	POS SYMBOL
TYPE	DEST	RESET	SPREAD OUT
RANGE 350	VECTOR 0	HIST 2	LEADER 2
FDB 70	LDB 60	TARGET 25	HIST 70
WX 50	BUTTON 100	BORDER 50	DC/CRD 50
MAP 1 15	MAP 2 0	SECTOR 35	SPEC 100
NEXRAD 100	TRACON 25	BKGRD 25	SLDB +00
MASTER 160	CURSOR 100	LINE 4 -0	DWELL +100
F-FONT 3	R-FONT 3	4 FONT 3	WAYPNT 40
SPEED 1	SIZE 04	VOLUME 1	ROUTES 100

RA MWL  
UPLINK FREQUENCY: ASQ763 133.15  
MC READY  
ZME-1

T AC FILTER +



# Near- to Mid-Term Controller Tools

- 4D trajectory generation for flight plan routing, scheduling, reported FMS trajectories, ADS-B reported state and flight control system targets
- Arrival scheduler and timelines
- Medium-term Conflict detection
- Trial planning and speed advisory functions for metering support
- Automation for automatic transfer of communication and RTA uplinks
- Multi-layered rapid feedback conflict probing
- Weather penetration probe
- Data comm. integration
- Fully automated, semi-automated, manual operations
- AAC Auto-Resolver with Weather avoidance
- Most functions are configured via the ATC DST Configuration

# Conflict Probe FDB

## Flight Data Block Conflict Information



### Font Color Coding for Time-to-Conflict values

- **Red Font:** time-to-loss of separation is < 3 minutes
- **Yellow Font:** time-to-loss of separation is > 3 minutes  $\leq$  5 minutes
- **White Font:** time-to-loss of separation is > 5 minutes but < 12 minutes

# Trial Planning

- Trial Plan Options

- Single or Multi-Aircraft
- Typed Commands into DSR CRD
  - FF- selects aircraft for group trial planning
  - TT- opens basic route trial plan
  - TA- opens an altitude trial plan
  - TR- opens a more specified route trial plan

## Multiple Aircraft Trial Plan- FF



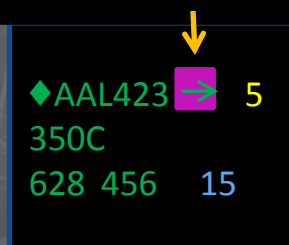
- Interactive Flight Data Block (FDB)

- Arrow next to the aircraft call sign- opens basic route trial plan
- Same arrow (but magenta-colored)- to review a suggested trial plan
- Altitude line of the FDB- opens an altitude trial plan
- Conflict number to start a automated trial plan resolution to solve for the predicted traffic conflict
- Weather number to start a trial plan to solve for the predicted weather penetration

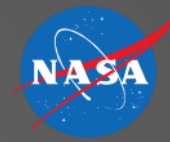
- Drag and Drop Route Line

- Lat/Long
- Waypoint

## FDB Trial Plan Portal







# Air/Ground Data Communication

## Key Uplink Capabilities

- Trajectory information [or parameters] and trajectory constraints (route modification uplinks, altitudes, profile speeds, required times of arrival)
- transfer of communication (i.e. frequency changes)
- free text (encode anything in text format)
- responses to aircraft initiated requests

## Key Downlink capabilities

- Responses (wilco, reject)
- Free text (encode anything in text format)
- Requested trajectory changes

## Broadcast/ downlink capabilities

- Aircraft state and velocities
- Short term intent and flight modes (i.e. flight control system settings )
- FMS trajectory reports
- FMS inputs (e.g. speed profile, weight)

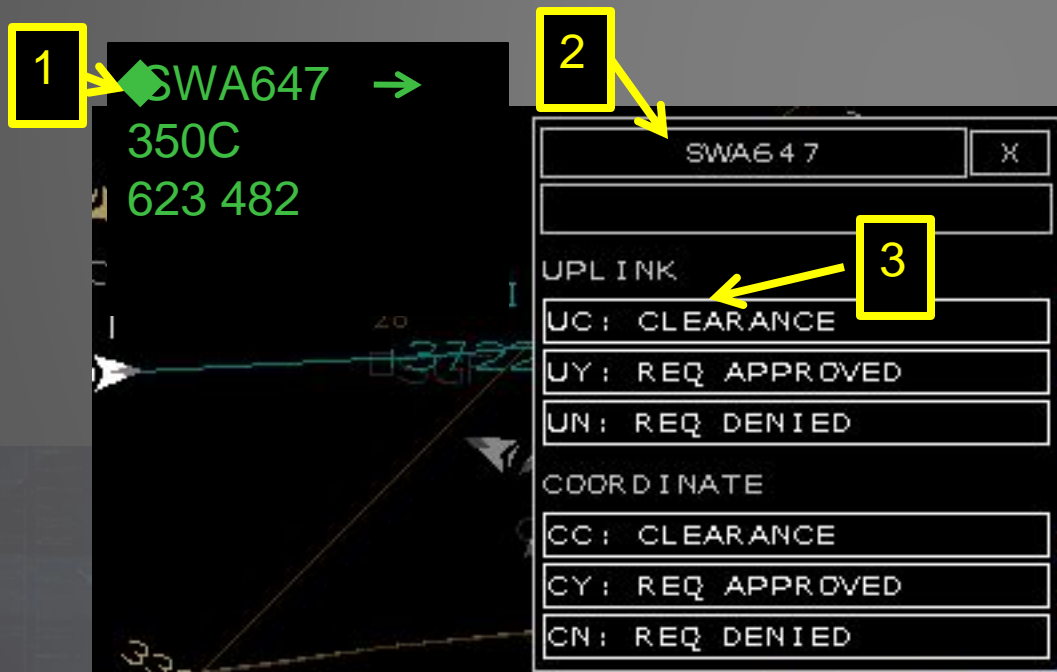


# Data Comm: Mixed Equipage Equipped Data Comm Clearance



## Uplink Clearance to Aircraft (Point and Click)

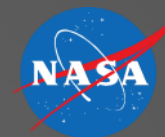
1. Pick on data link portal (filled triangle)
2. Drop down box appears next to FDB
3. Pick on UC: Clearance to uplink to aircraft



## Uplink Clearance via Keyboard

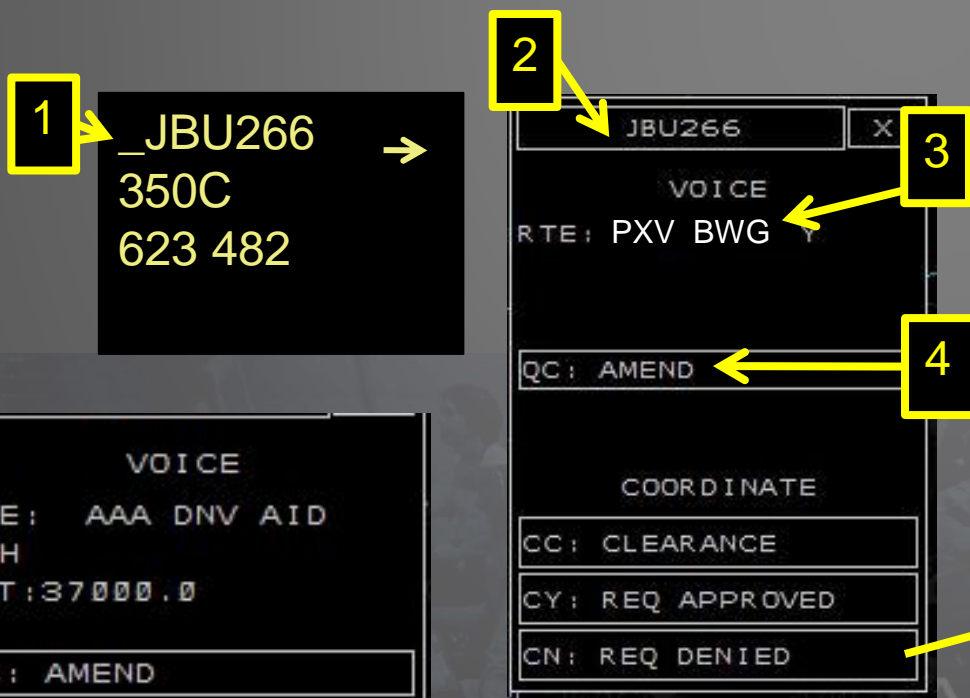
- Type UC [CID] ENTER

# Data Comm: Mixed Equipage Un-Equipped Verbal Clearance



## Issue TP or CC Clearance to Aircraft (Point and Click)

1. Pick on data link portal (underscore symbol)
2. Drop down box appears next to FDB
3. Voice clearance appears, issue to aircraft Direct PXV, BWG rest of route unchanged
4. Pick on QC: Amend in Automation (HOST)



# Data Comm FDB Information

◆ AAL207 →  
350C  
623 482

◇ \_AAL207 →  
350C  
623 482

⚡ AAL207 →  
350C  
623 482

↑ AAL207 →  
350C  
623 482

status the following data link status symbols are found in the flight data block (left of the call sign):

symbols ◆ : eligibility ◇ : no eligibility ⚡ : TOC in progress ↑ : uplink in progress

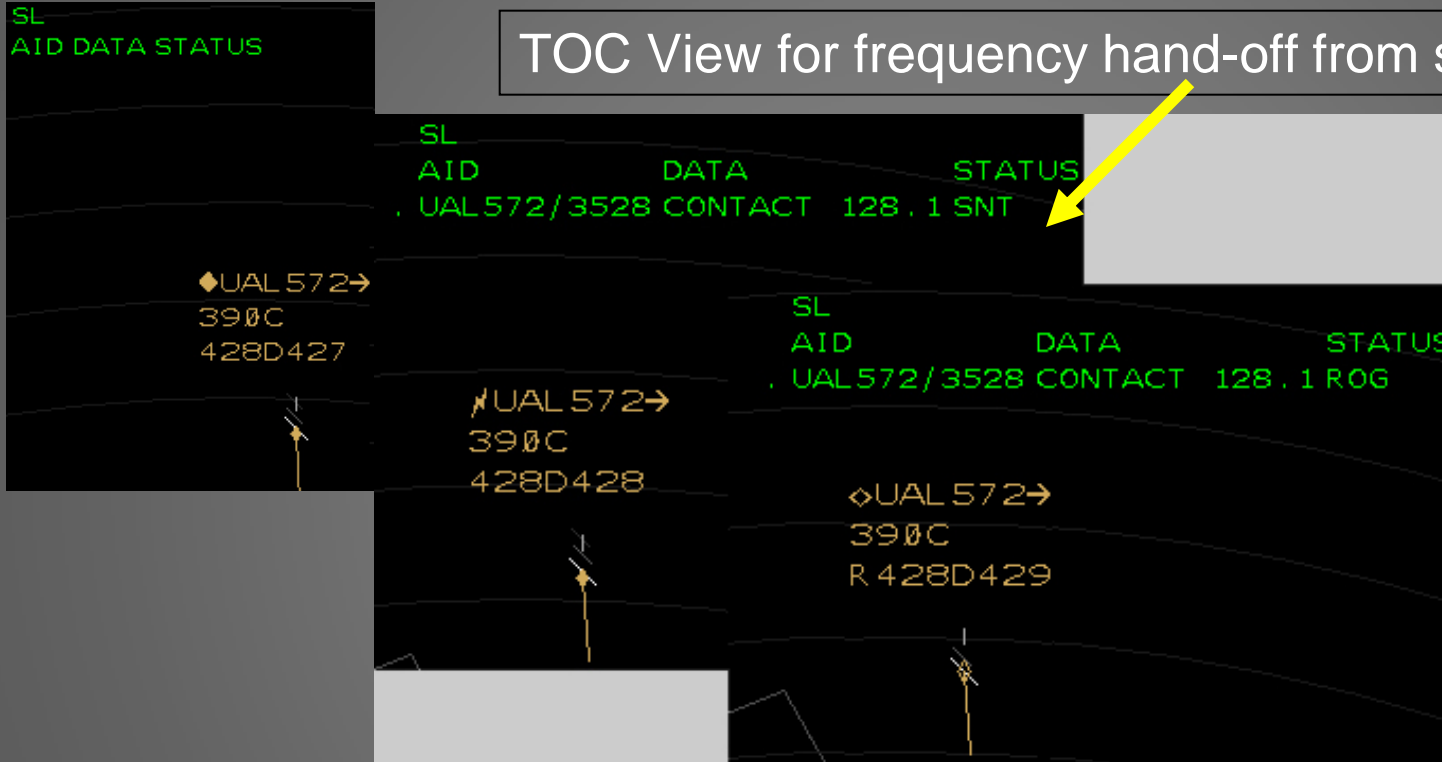
→ : coordination request (right of callsign)

- A filled diamond (◆) indicates that the sector has “eligibility”, and can send and receive messages to the aircraft. Data link eligibility usually accompanies track control, but the transfer mechanism is separate.
- An unfilled diamond (◇) indicates that the sector does not have “eligibility” (i.e., cannot communicate with this aircraft via CPDLC).
- A lightning bolt (⚡) indicates that a transfer of communication (and transfer of eligibility) is in progress.
- An up arrow (↑) indicates that a message has been “uplinked” from the controller to the aircraft. The uplink may be a clearance, frequency, or text message.
- A magenta arrow (→) indicates a coordination request which is a clearance request sent to the CPDLC eligible controller from another ground position or MSP.

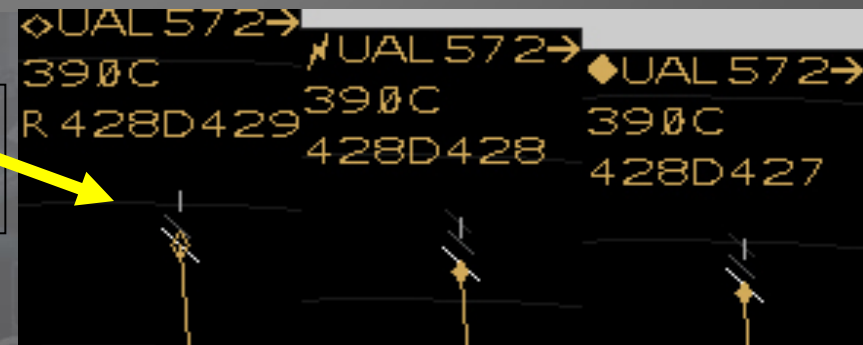
# Sample Data Comm Transfer of Communication (Air-to-Ground)



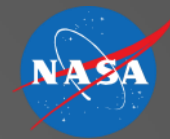
TOC View for frequency hand-off from sending sector:



TOC View for accepting hand-off  
frequency change from receiving sector:



# Sample Data Comm Request from Planners (Ground-to-Ground)



SL	AID	DATA	STATUS
FLG271/	428	RTE(IOW)	CC-RCV

2

FLG271	310C	428	421
◆			

1

OC	AUTO	SL	AID	DATA	STATUS
		FLG271/	428	RTE(IOW)	SNT
		FLG271/	428	RTE(IOW)	CC-ACC

4

FLG271	310C	428	430
↑			

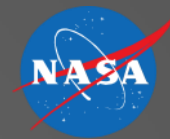
TOY  
+N38409W089574 310  
+N38307W08958215W0310

FLG271	310C	428	421	H312	2:33	IOW
◆						

3

## Coordination Request from MSP

1. Pink coordination request in FDB
2. Coordination Request Received in data link status list.
3. PICK on Request Portal to view request (pink route line).
4. UC up to aircraft to send route to aircraft and acceptance to Planner.



Multi Aircraft Control System (MACS)

# MULTI SECTOR OPERATIONS MID-TERM / 2022

25 aircraft are allowed in Airspace “sectors” at any given time  
1 or 2 Air Traffic Controllers per sector possible  
Video shows 7 controllers handling ~150 aircraft and several  
Traffic managers and Multi Sector Planners



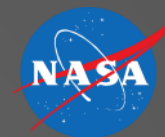


# Air Traffic Control in the Mid-Term





# Planner Stations



## Area Supervisor & Traffic Management Unit



Traffic situation display (TSD) with weather loop  
Interactive DSR display with traffic filters, weather penetration probe, multi-aircraft trajectory planning with optional weather and conflict avoidance resolutions.

Interactive sector load graphs and load tables

Data communication status list

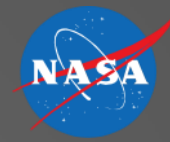
Boundary Edit window

Dynamic filter control panel, including To/From, VIA, FL, DRAW, WX, conflict, and equiPAGE category

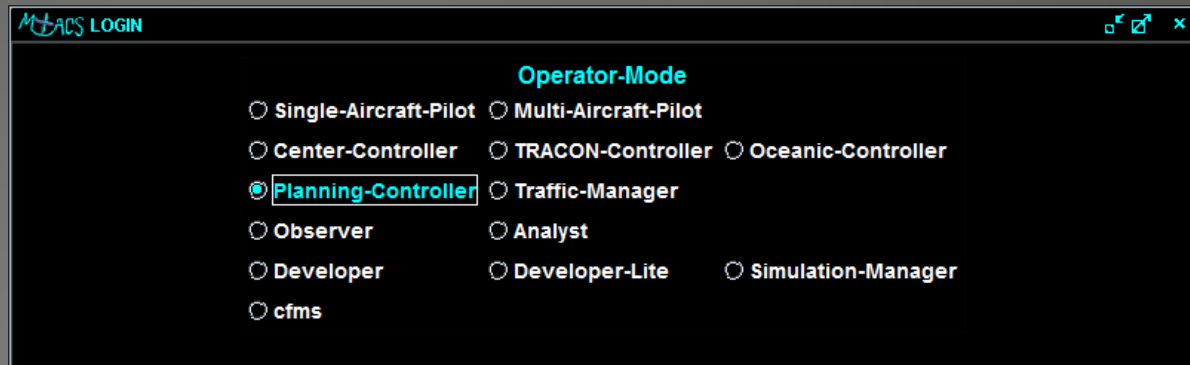
VSCS emulation for voice communication system

Control window for load table and load graph parameter selection

# Planning Controller Positions



## Operator-Mode: Planning-Controller



## Primary Displays: DSR View

DSR: Display System Replacement

TSD: Traffic Situation Display

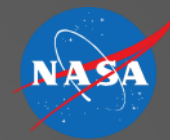
Load tables and graphs



## Most Relevant Setup Files:

- ATC DST Configuration
- ATC DST Sector Configuration
- DSR/TSD Data Tag Rules Setup
- DSR/TSD Plan View Setup
- DSR/TSD Sector Plan View Setup
- DSR/TSD Timeline Setup
- Traffic Load Setup

# Flow Based Trajectory Management Tools Assessment and Modification

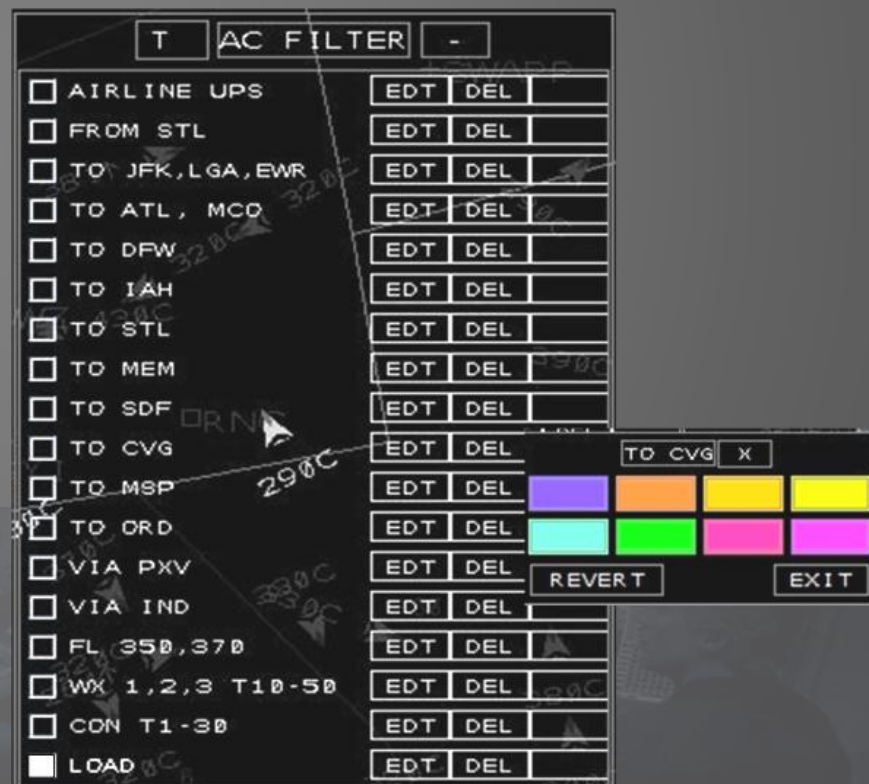


- Assessment Tools
  - Load Display Control Window
  - Load Table Window
  - Load Graph Window
  - Aircraft (AC) Filters
- Modification Tools
  - “trial plans” for single or multi-aircraft trajectories
    - Altitude
    - Route
    - Both Altitude and Route
  - Conflict avoidance, Weather avoidance or Airspace congestion
- Coordination Tools
  - Air-to-Ground Data Comm
  - Ground-to-Ground Data Comm



# Situation Assessment Tools

- AC Filter
  - Gain awareness of current and predicted traffic subsets
  - Highlight particular aircraft sets
    - TO or FROM specific airports
    - VIA routes or waypoints
    - FL- specific altitude stratum
    - GEO specific areas
    - DRAW-dynamically drawn objects
    - WX- forecasted weather areas
    - LOAD- traffic load and complexity tables/graphs
    - Color Code optional
    - ETC....





# Situation Assessment Tools (Cont)

## Load Tables and Graphs

- Traffic Loads
- Tables/Graphs
  - Specific Sector
  - Specific Time (15 min. intervals)
- Complexity Factors
  - Unequipped
  - Transitioning aircraft
  - Conflict predictions
  - Weather penetrations
  - Sector shape and size

**LoadTable with Complexity Values**

ZKC_47	20	24	30	27	20	22	21
ZKC_92	9	10	16	18	28	27	17
ZKC_94	28	30	34	34	28	42	37

**Load Display Control Window**

Cell values:  TOTAL  PEAK  AVERAGE  PEAK/TOTAL

Categories:  ALL  CNFLT\_CNT  CNFLT\_AC  TRANS  FILTR  UNEGOP  WETHR  CNPLX

Show Category only  Show Category and ALL

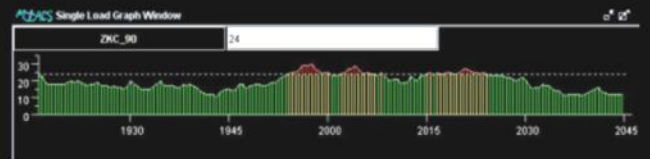
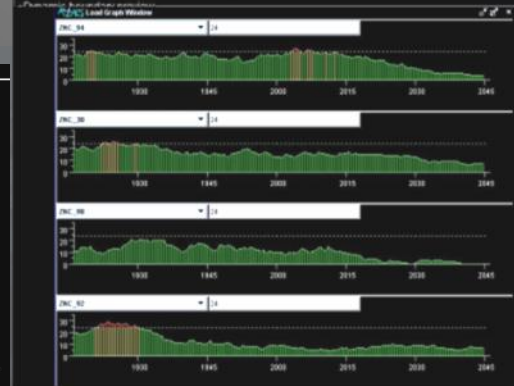
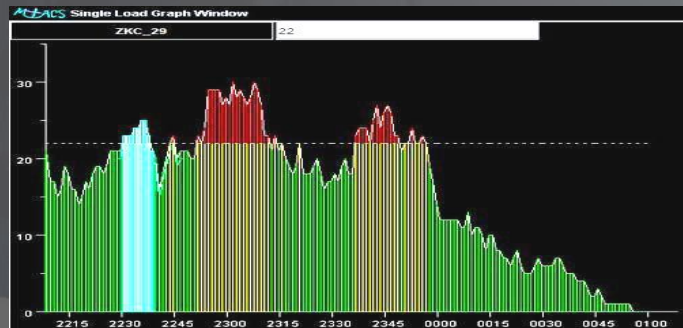
Selection logic:  Single cell  In any cell  Multi cell  In all cells

Deselect all

Display: Table font size: 2

**Load Table Window**

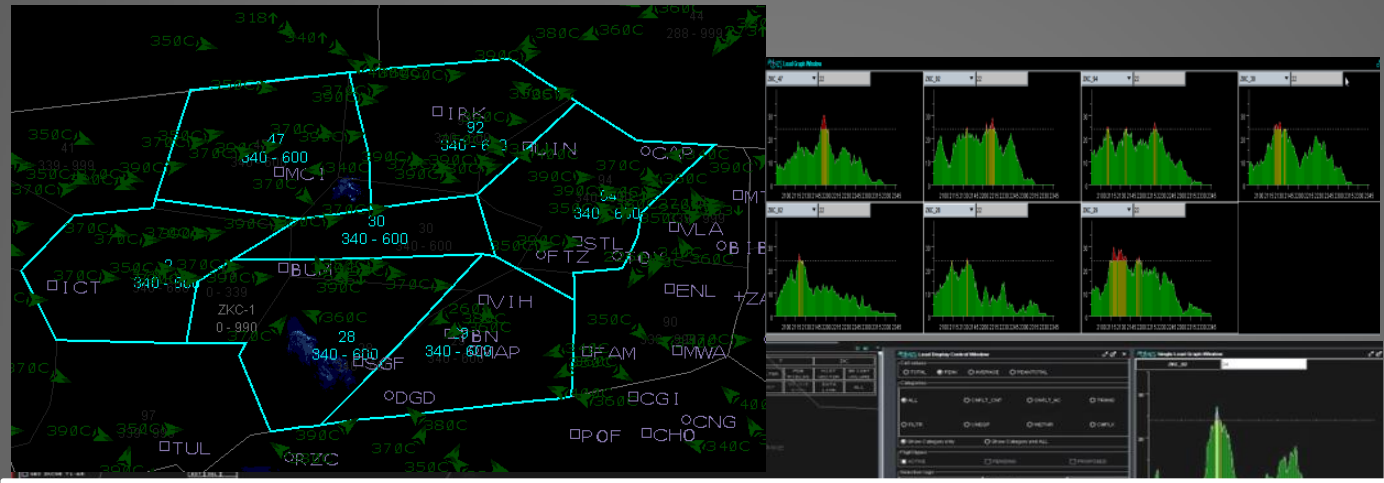
ZKC_28	26	21	20	22	19	17
ZKC_98	21	21	16	15	9	3
ZKC_98	23	20	30	39	27	20
ZKC_94	25	23	22	27	20	10
ZKC_92	29	24	13	9	10	9
ZKC_36	26	23	20	17	17	13
ZKC_28	23	19	18	15	10	8



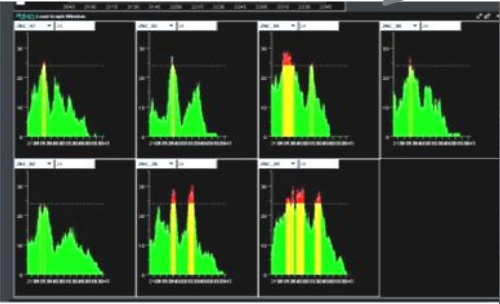
Load Display Control Window, Load Tables and Load Graphs

# Situation Assessment Tools (Cont)

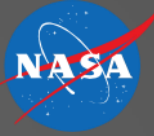
- Flexible Airspace Management with Dynamic Airspace Configurations



- Peak traffic reduced significantly
- Additional reroutes necessary



# Situation Assessment Tools (Cont)



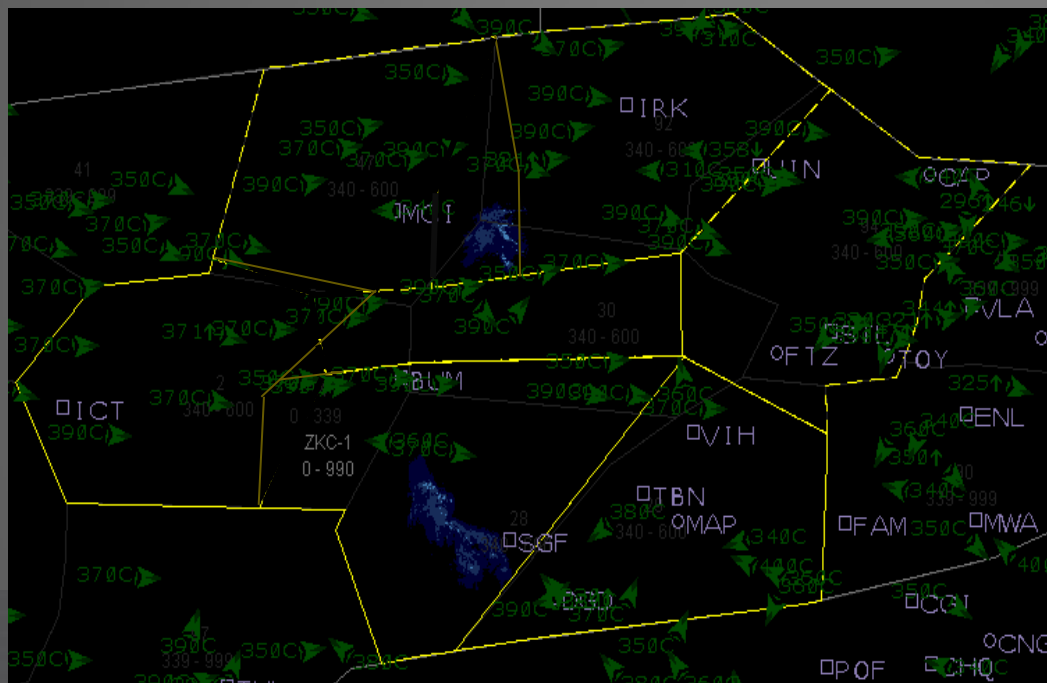
## Flexible Airspace Management Video





# Situation Assessment Tools (FAM Cont)

Select, share, and coordinate the configuration with other Sups/ TMCs



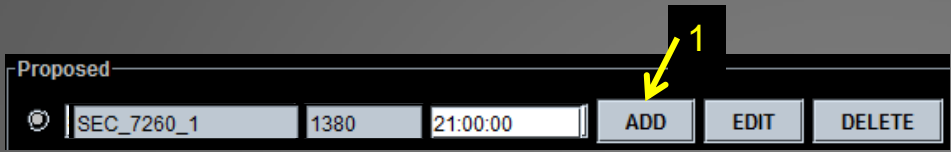
- Coordinate with other Sups and TMCs to implement the new airspace configuration
- Share the airspace configuration with other Sups and TMCs
- Call the Sups/TMCs and ask them to review the configuration
- Agree on the time to make the configuration change

Editable

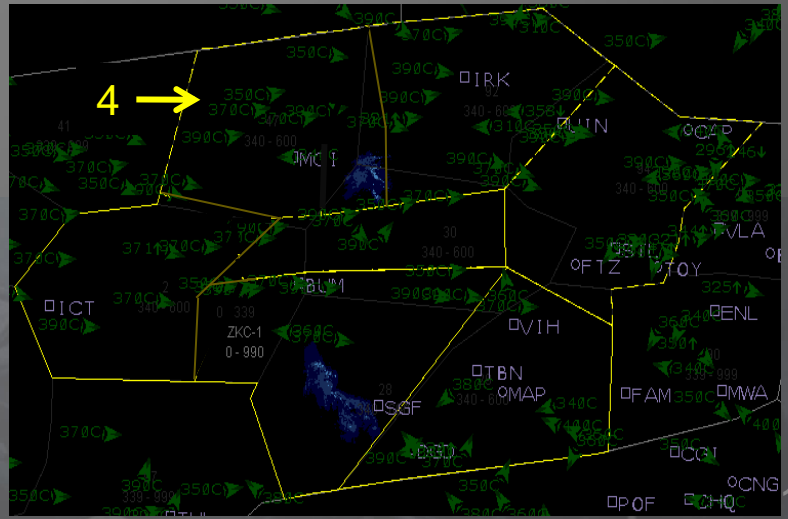
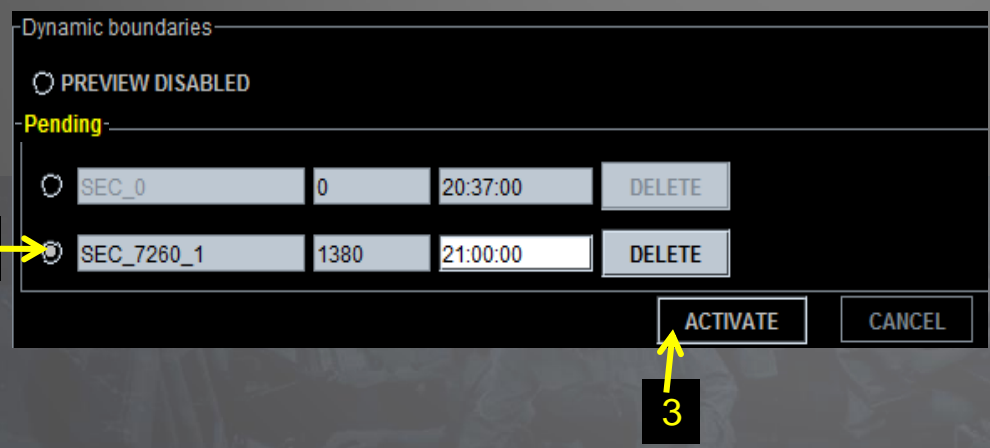
SEC\_7260\_1 COPY DELETE SHARE

# Situation Assessment Tools (FAM Cont)

## Implement (activate) the configuration change



1. Set the UTC time when the airspace configuration will change
  - Set UTC at 10+ min into the future to allow Sup-controller coordination and 5 min boundary preview
2. New configuration is moved to “Active area”
3. Click on ACTIVATE button to put the new configuration in the queue.
4. The new configuration will be active at the assigned UTC time.



# Situation Assessment Tools (FAM Cont)

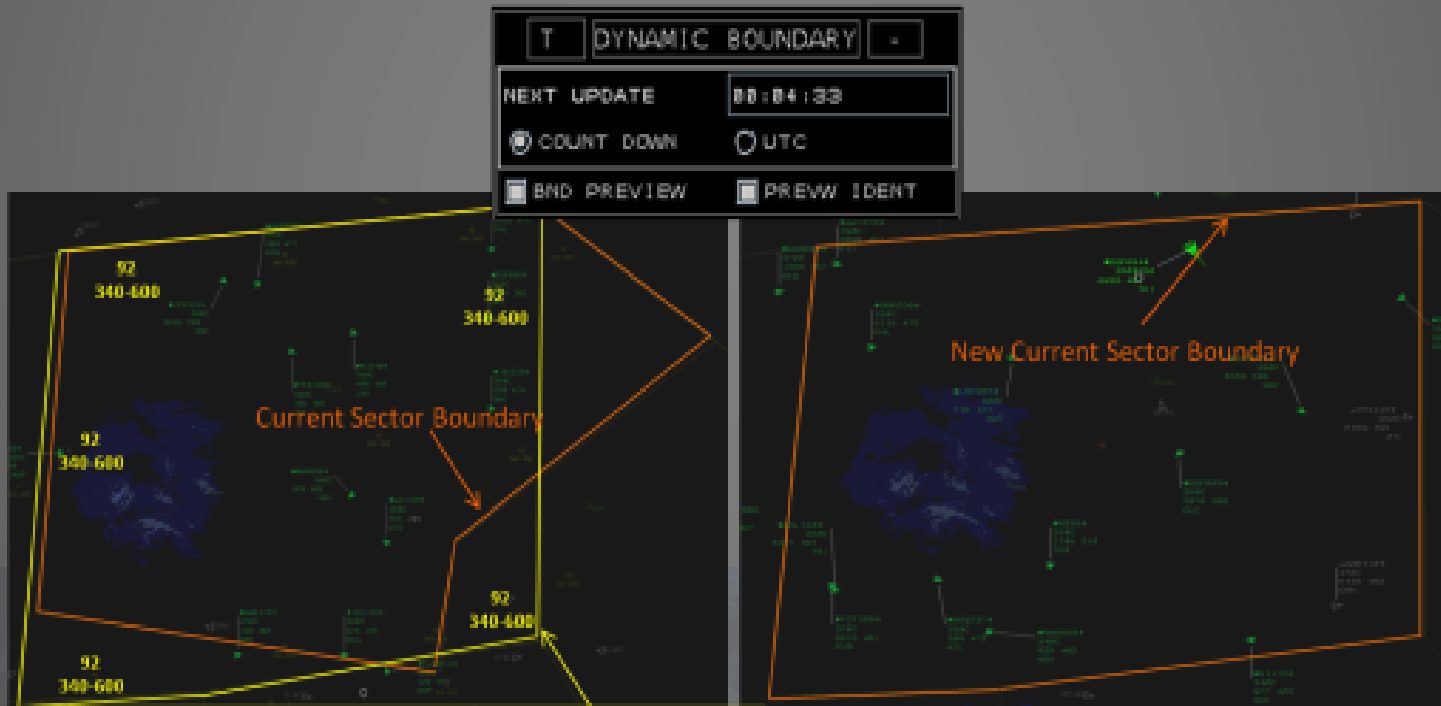


- Sup informs the controllers that a configuration change is planned.
- Sup displays the new configuration on the overhead projector.
- Controllers see the preview of the new airspace boundaries at 5 minutes prior to the change.

# Situation Assessment Tools (FAM Cont)

- Boundary Preview for the Controllers

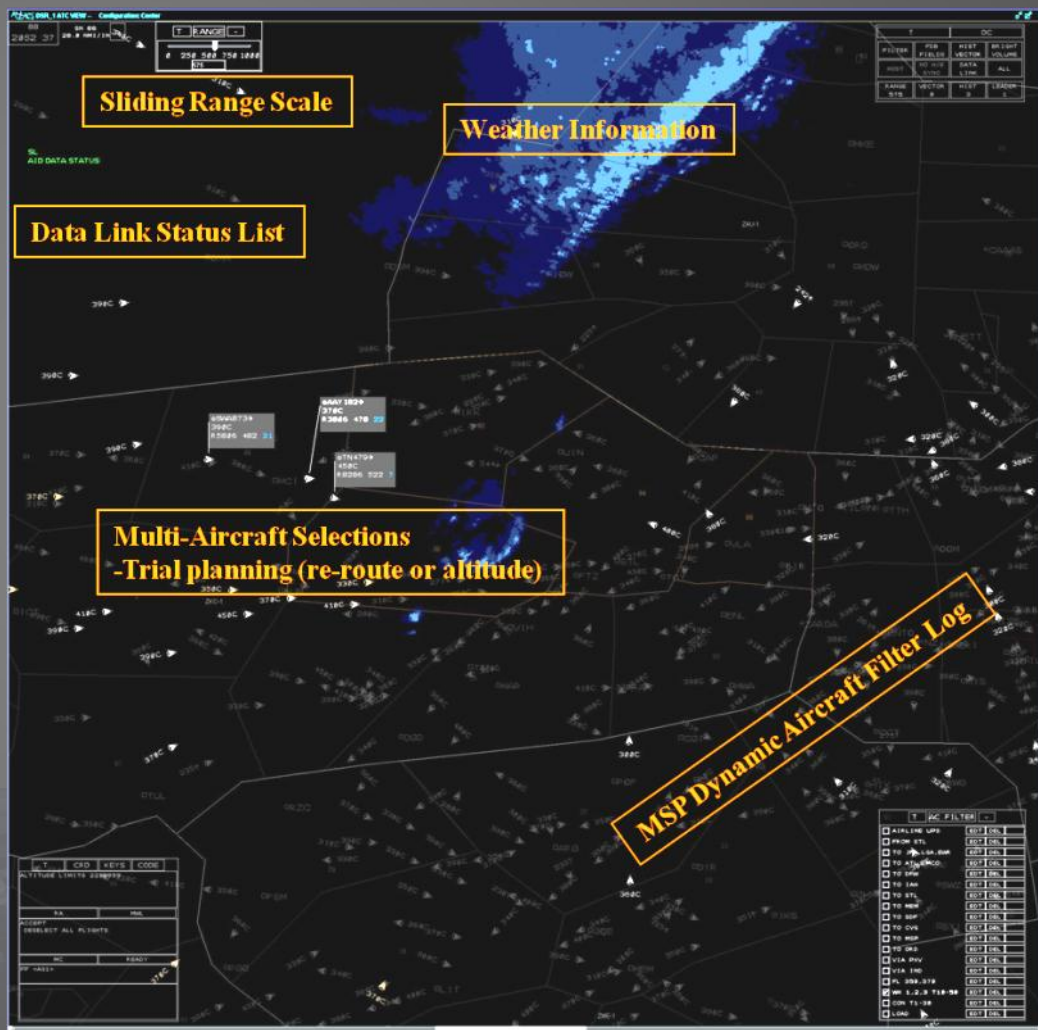
•Current Sector Boundary  
 •Future Dynamic Boundary Sector Change (to occur in 4 min. 33 sec.)



Future Dynamic Boundary Sector Change with new sector number and altitude next to all borders

# Trajectory Planning and Coordination

- Display System Replacement (DSR)
  - Interactive Trial Planning Tool
    - Single or Multi-aircraft
    - Altitude, Route, or Both
  - AC Filter Options
  - Data Comm
    - Air-to-ground
    - Ground-to-ground
  - Weather Information





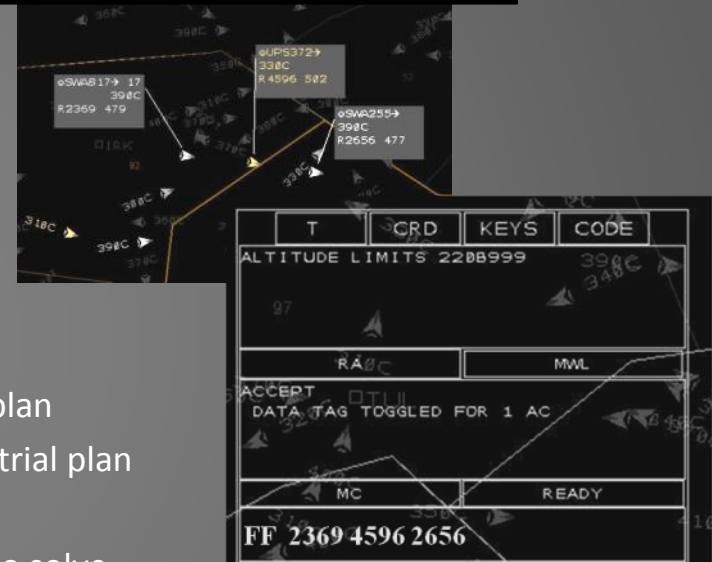


# Trajectory Planning and Coordination

- Trial Plan Options

- Single or Multi-Aircraft
- Typed Commands into DSR CRD
  - FF- selects aircraft for group trial planning
  - TT- opens basic route trial plan
  - TA- opens an altitude trial plan
  - TR- opens a more specified route trial plan

Multiple Aircraft Trial Plan- FF



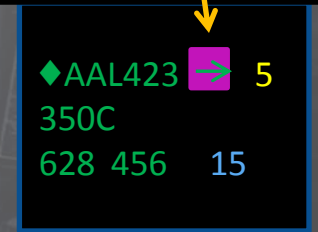
- Interactive Flight Data Block (FDB)

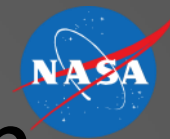
- Arrow next to the aircraft call sign- opens basic route trial plan
- Same arrow (but magenta-colored)- to review a suggested trial plan
- Altitude line of the FDB- opens an altitude trial plan
- Conflict number to start a automated trial plan resolution to solve for the predicted traffic conflict
- Weather number to start a trial plan to solve for the predicted weather penetration

- Drag and Drop Route Line

- Lat/Long
- Waypoint

FDB Trial Plan Portal

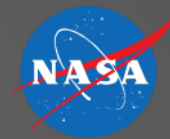




# Trajectory Planning and Coordination

- Trajectory Plan Coordination via Data Comm
  - Ground-to-Air Data Comm
    - Uplink the trajectory modification directly to the aircraft
  - Ground-to-Ground Data Comm
    - Coordinate the clearance with the radar controllers who have track control of those aircraft, upon approval, they can uplink it to the aircraft directly
    - Send a modified Coordination Plan to other team members
  - Voice Communications: VSCS Emulation
    - Available at all times (one to one or party line)
    - Required for Mixed-equipage





Multi Aircraft Control System (MACS)

# AIR TRAFFIC CONTROL OPERATIONS FAR-TERM / 2030

30, 40, or 50 aircraft are allowed in Airspace “sectors” at any given time  
1 or 2 Air Traffic Controllers per sector possible  
Video shows 8 controllers handling ~300 aircraft



# Air Traffic Control in 2030 ...



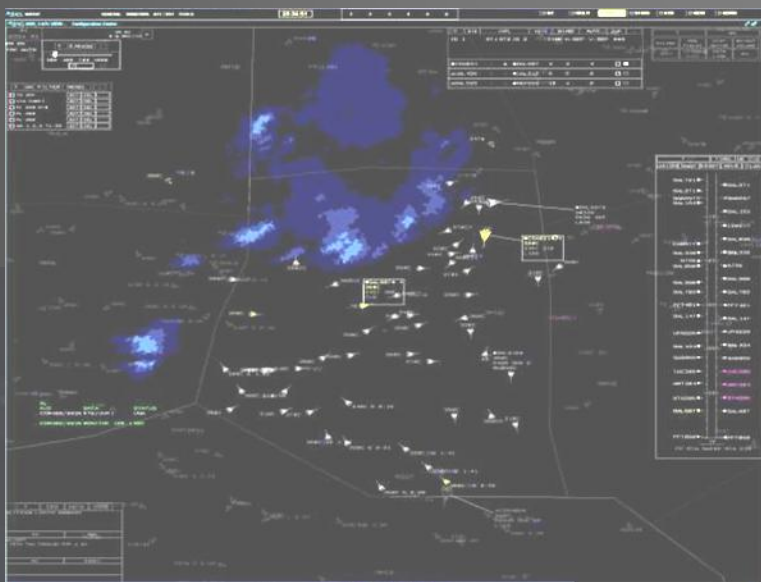
# Function Allocation used in Study

## Automation

- Detect Separation and weather Conflicts
- Resolve trajectory-based conflicts (if within tolerances)
- Resolve all time-critical traffic conflicts
- Alert controller to urgent problems
- Provide trajectory planning assistance
- Use data comm. to communicate

## Controller

- Supervise the automation
- Resolve trajectory conflicts flagged by the automation
- Monitor and maintain schedule compliance
- Implement weather reroutes with automation support
- Place aircraft back on trajectory following automated tactical maneuvers

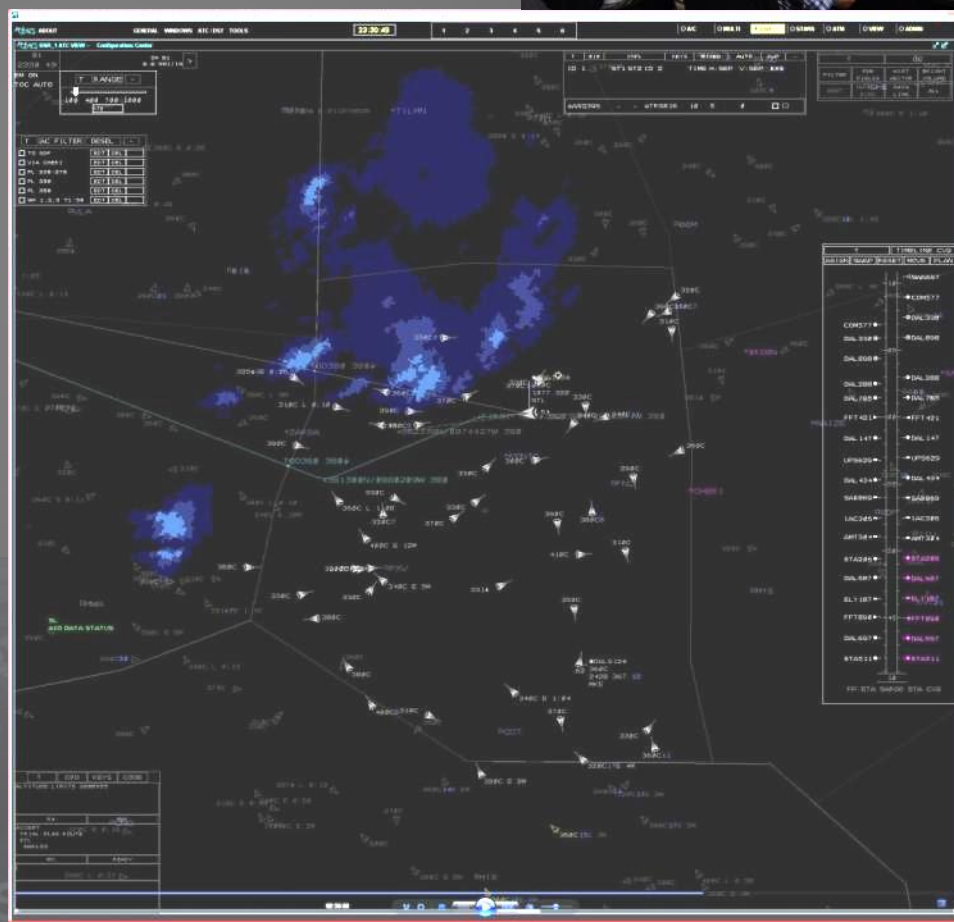




# Prototype System

Integrated controller workstation with

- Trajectory planning
- Data communication
- Conflict probing
- Trajectory-based conflict resolution
- Short-term conflict alert and resolution
- Weather avoidance
- Scheduling and time-based metering



# Trajectory-based CD&R

T	DD	CNFL	KEYS	MIXED	AUTO	SUP	-		
FONT	M-MINS	A-MINS	LBL	UNT	ST	TIM	HS	VS	BXS
ID 1	ST 1	ST 2	ID 2	TIME	H-SEP	V-SEP	BXS		
◆SAS 489	↓	↓	↑TAS573	1	4	8	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
◆AFR 689	-	↓	◆SAS 489	4	5	8	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
◆AFR 689	-	↓	↑TAS573	9	2	0	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
○AMC931	-	-	○SVA894	9	5	0	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
○ACA277	-	↓	○ACA471	9	0	9	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

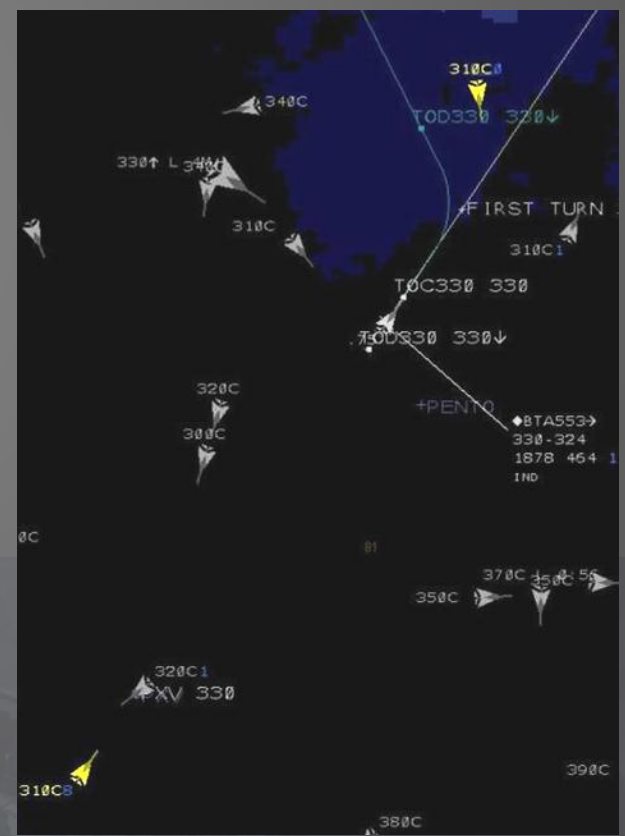
**Conflict Selection Boxes**  
-Pick this box if you want to mark that conflict for review

**Data Link Status Symbols**

**Separation Assurance Resolution Status Boxes**

- Yellow: controller assistance needed
- Cyan: trial plan trajectory present
- Green: conflict solved, up link sent
- Blank: no action has been taken yet
- White: automatic resolution started

Automation status indication integrated in relevant places on the displays (e.g. resolution, conformance data link status)





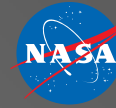
# Tactical Short-Term CD&R

Vectoring solutions are highlighted in data tag and sent by the automation

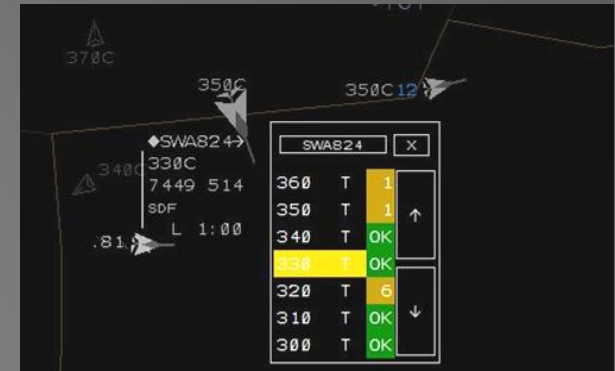




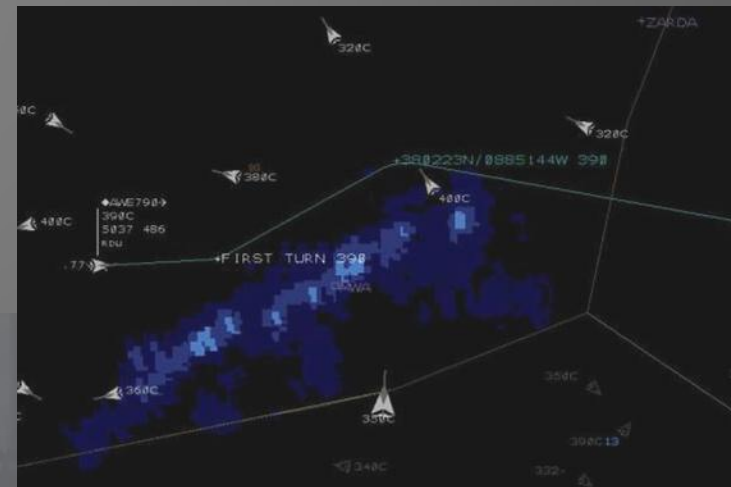
# Improvements

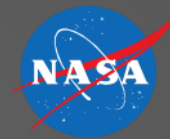


- Automation
  - Altitude fly-out menu with real-time conflict feedback
  - Free-track trajectory automation
  - Semi-automated weather avoidance



- Human Automation Interaction and Procedures





# Questions?

Tom Prevot, Connie Brasil, Michael Kupfer,  
Joey Mercer

