

Flight Test Management Centers, Receiving Systems and Frequency Allocation / Management System

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Abstract:

Telemetry systems and Flight Test Management Center-supported flight test operations require systematic resource management. During test campaigns, critical assets, including airborne telemetry frequencies, ground receiving systems (Receiver Units, Best Source Selectors, Receiving Antennas), Flight Test Management Centers and operational personnel must be coordinated through a centralized framework. To address this operational complexity, an integrated decision support platform enables centralized planning, monitoring, and control of these resources. This approach optimizes telemetry frequency utilization according to aircraft data acquisition requirements through spectrum analysis and conflict detection. Potential frequency overlaps and RF interference risks are identified during planning, allowing mitigation prior to execution. Mission pattern, onboard telemetry system configuration, and link budget-based allocation logic support algorithm-driven assignment of receiving antennas and ground infrastructure. Resources such as Flight Test Management Centers and personnel are allocated based on test scope and predefined algorithms to ensure efficient utilization. The modular architecture incorporates prioritization, reservation, and controlled reallocation mechanisms, enabling deterministic and traceable resource management. This approach shortens preparation cycles, improves infrastructure efficiency and optimizes resource utilization across flight tests, ensures link budget-compliant antenna/receiving system allocation, and significantly reduces human-induced configuration errors in receiving configurations.

Key words: Flight Test Resource Management, Spectrum Conflict Detection, Telemetry Frequency Allocation, Link Budget-Based Antenna Assignment, Ground Receiving System Allocation

Introduction

Telemetry systems constitute a critical component of flight test operations at Turkish Aerospace, enabling real-time data acquisition, monitoring, and mission safety assurance across a wide range of fixed-wing platforms such as Hurjet, TF-X (KAAN), Hurkus; rotary-wing platforms such as Gokbey, Atak and Unmanned Aerial Vehicle (UAV) platforms such as Anka, Aksungur, ANKA-III.

Flight test campaigns at Turkish Aerospace are increasingly characterized by high operational density, driven by the growing number of prototype aircraft under development and the parallel execution of multiple development

programs flight test campaigns. Multiple test activities are conducted within the same day and, in many cases, executed simultaneously, significantly increasing the complexity of telemetry operations. In such high-density environments, the coordinated use of a limited set of interdependent operational resources becomes a central planning challenge. These challenges make impossible to plan all of the flight test process manually and a centralized management system need becomes mandatory for these missions.

Flight test resource management involves the simultaneous coordination of multiple interdependent components, including airborne telemetry frequencies, ground receiving systems

(receiver units, best source selectors, and receiving antennas), Flight Test Management Centers (FTMCs), and operational personnel. These elements must be assigned in a consistent, conflict-free, and performance-aware manner while satisfying mission-specific requirements and operational constraints.

However, existing planning practices are predominantly based on manual processes and operator experience. Decisions such as FTMC assignment, receiving antenna selection, telemetry frequency allocation, and personnel scheduling are performed independently by different stakeholders, without an integrated view of the overall operational context. As the number of concurrent missions increases, this approach becomes increasingly inadequate, leading to issues such as frequency conflicts, suboptimal antenna selection, FTMC resource contention, and inefficient utilization of ground infrastructure. The dynamic nature of flight test operations further complicates planning, as activity durations, start times, and mission scopes frequently change during the day, requiring continuous re-coordination of all affected resources.

Compounding these process-level challenges, the planning environment also lacks a unified data structure that consolidates platform-specific telemetry parameters, receiving system characteristics, and operational airspace definitions within a single integrated platform. As a result, interdependent resources are evaluated in isolation, using data that is often distributed across multiple tools, spreadsheets, and individual records, which limits traceability and the ability to enforce consistent planning rules across missions.

To address these challenges, Turkish Aerospace has developed and deployed the Flight Planning and Management System (FPMS), an enterprise platform that consolidates all flight test planning and operational data in a single environment. FPMS provides a comprehensive tracking environment for the entire flight test organization: it maintains detailed records for test pilots, flight test engineers, and ground support personnel, including qualification records and aircraft type ratings, license validity periods, recurrent training and proficiency check schedules, medical certificate statuses with expiration tracking, security clearance levels, and role-specific authorizations. Crew duty-time and rest-time constraints are continuously monitored against regulatory and organizational limits — daily, weekly, monthly, and rolling-window flight

and duty hours — and assignments that would violate these limits are automatically blocked or flagged. On the asset side, FPMS tracks aircraft tail-numbers, configuration baselines and modification statuses, scheduled and unscheduled maintenance windows, ground equipment availability, and consumable resource inventories, ensuring that operational plans remain consistent with both crew readiness and aircraft airworthiness at all times. It performs weather check using meteorological data sources such as OGIMET and Hezarfen/RASAT, and retrieves METAR and TAF data. The NOTAM information, which is critical for the execution of flight operations, is available within the system, and the system provides alerts when necessary. Within FPMS, TULPAR [1] is the dedicated subsystem responsible for telemetry resource management and Flight Test Management Center (FTMC) operations, and it serves as the central operational system for flight test activities. Unlike conventional planning tools, TULPAR maintains a controlled operational data model as part of the platform itself, in which primary system definitions — aircraft types, projects, airports, mission types, FTMC configurations, and telemetry frequencies — are established as foundational data definitions and used as the reference basis for all planning decisions. Mission-specific records are consistently linked to these definitions, ensuring that every operational decision is traceable to a centrally managed data set. The platform is actively used by multiple stakeholders across the flight test organization, providing each role with a consistent view of the same underlying data.

TULPAR is organized into a set of interconnected modules that collectively cover the planning and execution of flight test missions from a telemetry perspective. The operational backbone consists of flight request, flight planning, and execution modules, supported by dashboard and calendar-based views that enable continuous monitoring and dynamic modification of daily activities, including rescheduling, cancellations, and mission updates. A reporting and analytics layer provide planning, performed, cancellation, and statistical reports across projects, platforms, airports, flight types, and activity categories, supporting both day-to-day decision-making and long-term performance evaluation. A dedicated set of modules is further allocated to telemetry and Flight Test Management Center operations, covering the definition of airborne transmitters and ground receiving systems, airspace and frequency management, reservation and scheduling of FTMC activities, and the

assignment of telemetry personnel — telemetry engineers and console operators — to scheduled FTMC activities, together with real-time operational dashboards. An overall view of the TULPAR platform is illustrated in Fig. 1.

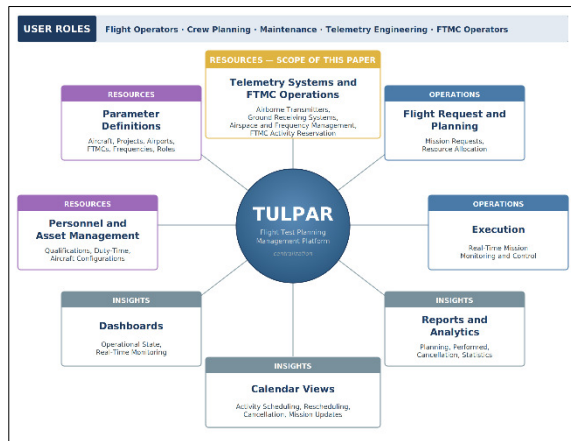


Fig. 1. TULPAR Overview.

The main contributions of this paper can be summarized as follows:

- an integrated telemetry resource management system that jointly considers airborne transmitters, ground receiving systems, FTMC configurations, and personnel resources within a unified data model;
- a link-budget-driven receiving antenna assignment approach based on worst-case operational airspace evaluation;
- a real-time spectrum management and frequency conflict detection mechanism covering aircraft–aircraft, aircraft–satellite, and aircraft–ammunition interactions;
- an automated multi-constraint allocation strategy for FTMCs, antennas, frequencies, and personnel under dynamically changing mission conditions; and
- a calendar-based planning workflow that maintains consistency across all resources and enables continuous re-evaluation during the planning phase.

Methodology

Architecture of the Telemetry Resource Management Modules

TULPAR is built on the Vaadin frontend with a PostgreSQL database, a Java-based user interface, the Highcharts library for interactive visualizations, and the BIRT reporting engine for structured reports. This software foundation provides the scalability and data integrity required for long-term operational deployment.

The telemetry resource management modules are organized into two main architectural layers: a definitions layer and a mission-based planning layer. The definitions layer maintains all telemetry-related system parameters required

for decision-making — airborne transmitter characteristics, ground receiving system properties, FTMC configurations, operational airspace definitions, and telemetry frequency data — summarized in Fig. 2.

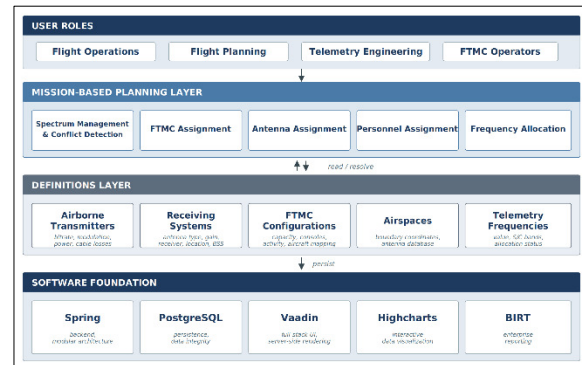


Fig. 2. Architecture.

The mission-based planning layer processes user-defined flight activities by evaluating mission parameters against these foundational definitions. Within this layer, five interdependent mechanisms operate in coordination: spectrum monitoring and conflict detection, automatic FTMC assignment, receiving antenna assignment, personnel assignment, and telemetry frequency allocation. Fig. 2 illustrates the overall architecture, including user roles with role-specific access. Each mechanism is described in detail in the subsequent sections.

Input Data and Operational Constraints

The telemetry resource planning process in TULPAR operates on a structured data model in which both static system definitions and mission-specific inputs are evaluated together. Static definitions are established once and maintained centrally within the definitions layer described in the previous section, while mission-specific inputs are provided at the time of flight planning. This integrated data-driven approach ensures that all planning decisions are performed against a consistent and traceable reference model, eliminating the ambiguity that arises from fragmented spreadsheets and manual record-keeping. Fig. 3 summarizes the system parameters maintained within the definitions layer, together with their units or data types and their role in the planning process.

Category	Parameters	Primary Role
Airborne Transmitters	Bit rate, modulation type, transmitter power, cable losses	Bandwidth & link budget calculation
Receiving Systems	Antenna type, gain, location, status, BSS, cable losses	Coverage, link budget, availability
FTMC Configurations	Aircraft, FTMC mapping, capacity, reservation status	FTMC assignment constraints
Airspaces	Boundary coordinates	Coverage suitability evaluation
Telemetry Frequencies	Frequency value, bandwidth	Spectrum interval computation

Fig. 3. Input Data.

Beyond the static parameters summarized in Fig. 3, the planning process incorporates a set of operational constraints that directly influence resource allocation decisions. These include FTMC capacity limitations, antenna availability within specific time intervals, system status conditions (e.g., active/inactive, BSS connectivity), and mission timing constraints. Assignment decisions are further governed by predefined rules such as antenna–FTMC compatibility, airspace-dependent suitability, and resource availability within the planning phase. Transmitting system definitions screen is illustrated in Fig 4. In this screen, transmitting system configuration could be saved and listed. For confidentiality reasons, the input data and parameter values in the screens masked in black.

Aircraft Type	Configuration	Mission ID	Mission Date	Launch/End Date	Transmitting System	Status
PCBM M11-20	20.832/	2018	40.07	1	Bottom Antenna	Not
PCBM M11-20	20.832/	2018	41.57	2	Top Antenna	Not
PCBM M11-20	9.0302	2018	40.07	2	Top Antenna	Not
PCBM M11-20	9.0302	2018	40.07	1	Bottom Antenna	Not
PCBM M11-20	9.0302	2018	40.07	1	Bottom Antenna	Not
PCBM M11-20	9.0302	2018	40.07	2	Top Antenna	Not
PCBM M11-20	11.7665	2018	39.57	2	Top Antenna	Not
PCBM M11-20	11.7665	2018	39.57	1	Bottom Antenna	Not
PCBM M11-20	11.7665	2018	39.57	1	Bottom Antenna	Not

Fig. 4. Transmitting System Definitions Screen.

FTMC Assignment

Flight Test Management Center (FTMC) assignment is the first step of the telemetry resource planning process, since the selected FTMC constrains the set of compatible receiving antennas, personnel qualifications, and operational procedures for the mission. TULPAR performs this assignment automatically by evaluating mission parameters such as aircraft type, activity type, and planned time interval against the FTMC definitions maintained in the system (Fig. 5).

FTMC ID	Capacity	Operational	Frequency	Location	Status
18	54	False	True	1	0
20	51	False	False	2	2
42	25	False	False	3	5
14	10	True	True	4	0
5	6	True	False	1	1
12	12	True	False	2	1
14	14	True	False	3	1
16	15	True	False	2	1

Fig. 5. FTMC Definitions List Screen.

When a mission plan is entered, TULPAR filters candidate FTMCs by aircraft-type compatibility, excludes those already booked in the requested time window, and verifies sufficient console capacity. From the remaining candidates, the

most appropriate FTMC is selected according to predefined allocation rules and the current utilization state.

If no FTMC satisfies all constraints, the mission is placed in a manual allocation list reserved for authorized telemetry administrators, ensuring planning continuity in unusual cases such as demand exceeding capacity or atypical platform configurations. After manual assignment, the entry is removed from the list and the mission resumes the standard planning flow.

Because mission parameters change frequently during planning, any modification to mission timing, aircraft configuration, or activity type automatically re-triggers the compatibility, availability, and capacity checks, and the FTMC assignment is updated accordingly. This keeps allocations consistent with the current planning state without manual revalidation.

Activity Type	Description	Planning Impact
Flight	Flight test activity supported by telemetry engineers	Occupies FTMC for full mission duration
Training	Telemetry engineer training sessions in the FTMC	FTMC unavailable for flight missions
TM System Test	Telemetry equipment verification & end-to-end checks	FTMC unavailable for flight missions
Maintenance	Scheduled maintenance of FTMC hardware/systems	FTMC removed from candidate pool
Out of Service	FTMC temporarily non-operational due to issues	FTMC removed from candidate pool
Field Mission	Field operation of mobile FTMC at external test site	FTMC reserved for the field operation window

Fig. 6. FTMC Activity Types in TULPAR.

Fig. 6 summarizes the activity types supported in TULPAR and their direct impact on the availability check. Any FTMC with an active non-flight activity (training, maintenance, out-of-service, or field mission deployment) within the requested time interval is excluded from the candidate pool before the capacity check is performed. The complete FTMC assignment flow is illustrated in Fig. 7.

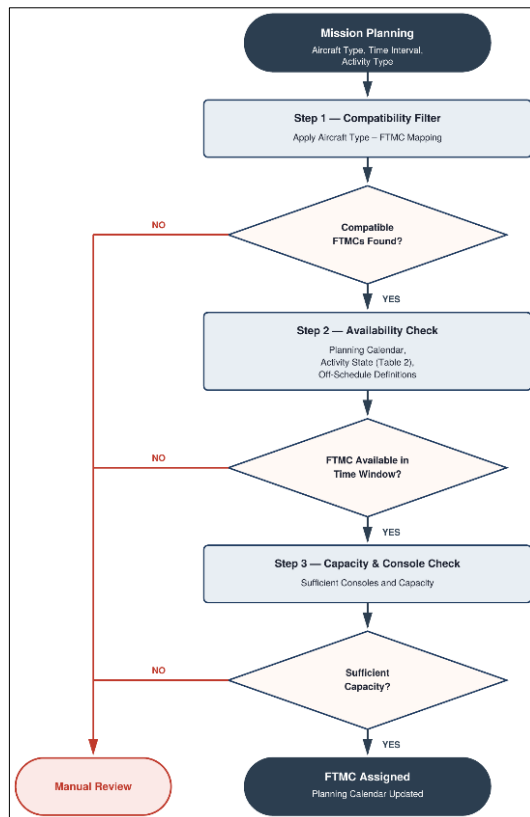


Fig. 7. FTMC Assignment Flow.

Receiving Antenna Assignment

Receiving antenna assignment is a critical step in telemetry resource planning, as the selected antenna directly determines the quality of the downlink between the airborne transmitter and the ground station throughout the mission. Unlike FTMC assignment, which is driven primarily by operational and capacity constraints, antenna assignment must additionally account for RF propagation conditions: the geographical relationship between the antenna location and the operational airspace, the link budget between the airborne transmitter and the candidate receiver, and the physical characteristics of the antenna itself (Fig. 8). This section focuses on tracking antennas used for in-flight operations, which must remain compatible with the FTMC selected in the previous step. Sector antennas, dedicated to parking and taxi operations, are assigned through a separate mechanism outside the scope of this section. An example of the receiving systems list screen, where the antenna definitions are maintained, is shown in Fig. 8.

Receiving System ID	Antenna Type	Antenna Location	Antenna Frequency	Antenna Power	Antenna Status	Antenna Notes
1	Sector Antenna	1	1	1	True	
2	Sector Antenna	2	2	2	True	
3	Sector Antenna	3	3	3	True	
4	Sector Antenna	4	4	4	True	
5	Sector Antenna	5	5	5	True	
6	Sector Antenna	6	6	6	True	
7	Sector Antenna	7	7	7	True	
8	Sector Antenna	8	8	8	True	
9	Sector Antenna	9	9	9	True	
10	Sector Antenna	10	10	10	True	
11	Sector Antenna	11	11	11	True	
12	Sector Antenna	12	12	12	True	
13	Sector Antenna	13	13	13	True	
14	Sector Antenna	14	14	14	True	
15	Sector Antenna	15	15	15	True	
16	Sector Antenna	16	16	16	True	
17	Sector Antenna	17	17	17	True	
18	Sector Antenna	18	18	18	True	
19	Sector Antenna	19	19	19	True	
20	Sector Antenna	20	20	20	True	

Fig. 8. Receiving Systems List Screen.

The automatic antenna assignment process operates on three categories of input data maintained in the definitions layer (Fig. 3): airborne platform parameters that characterize the transmitter, ground receiving system parameters that characterize each candidate antenna, and mission-specific inputs. The mission-specific inputs include the operational airspace, defined as a polygon of geographical boundary coordinates, together with the FTMC assigned in the previous step, which restricts the candidate antenna set through the FTMC–antenna mapping. These inputs are evaluated together to determine whether a candidate antenna can provide sufficient coverage over the entire operational airspace. The overall antenna selection flow is summarized in Fig. 9.

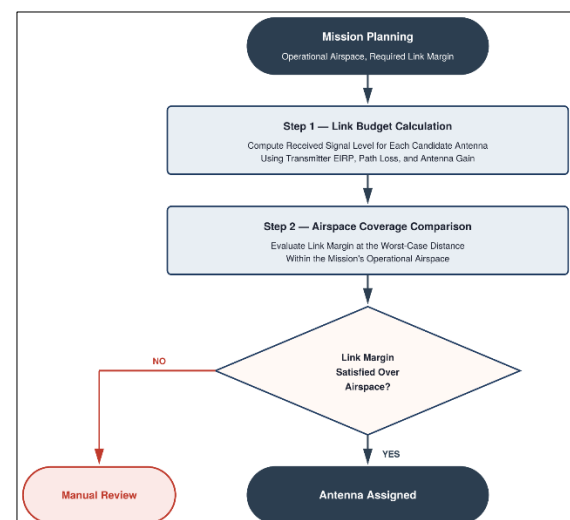


Fig. 9. Antenna Assignment Flow.

The coverage suitability of each candidate antenna is evaluated using a worst-case link-budget approach. The antenna selection problem is formulated as a coverage feasibility evaluation over the operational airspace. For each candidate antenna location q , the system determines the worst-case distance within the mission area:

$$d_{\max}(q) = \max \| p_i - q \|$$

Instead of relying on nominal proximity, the system evaluates whether the communication

link remains feasible under worst-case conditions across the entire operational airspace. A candidate antenna is considered suitable only if it satisfies the link feasibility condition derived from system and mission requirements. This approach ensures that antenna selection is driven by guaranteed worst-case performance rather than nominal proximity. Antenna assignment for one airspace is illustrated in Fig. 10.

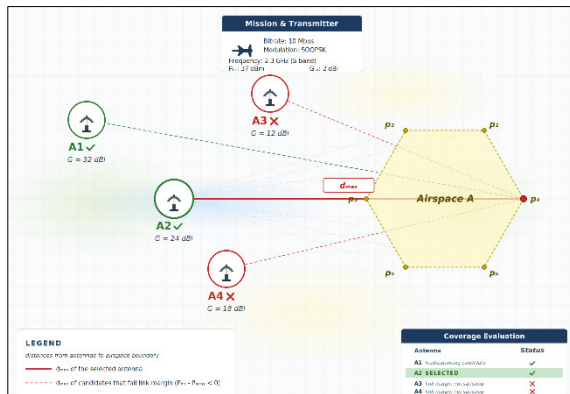


Fig. 10. Antenna Assignment for One Airspace.

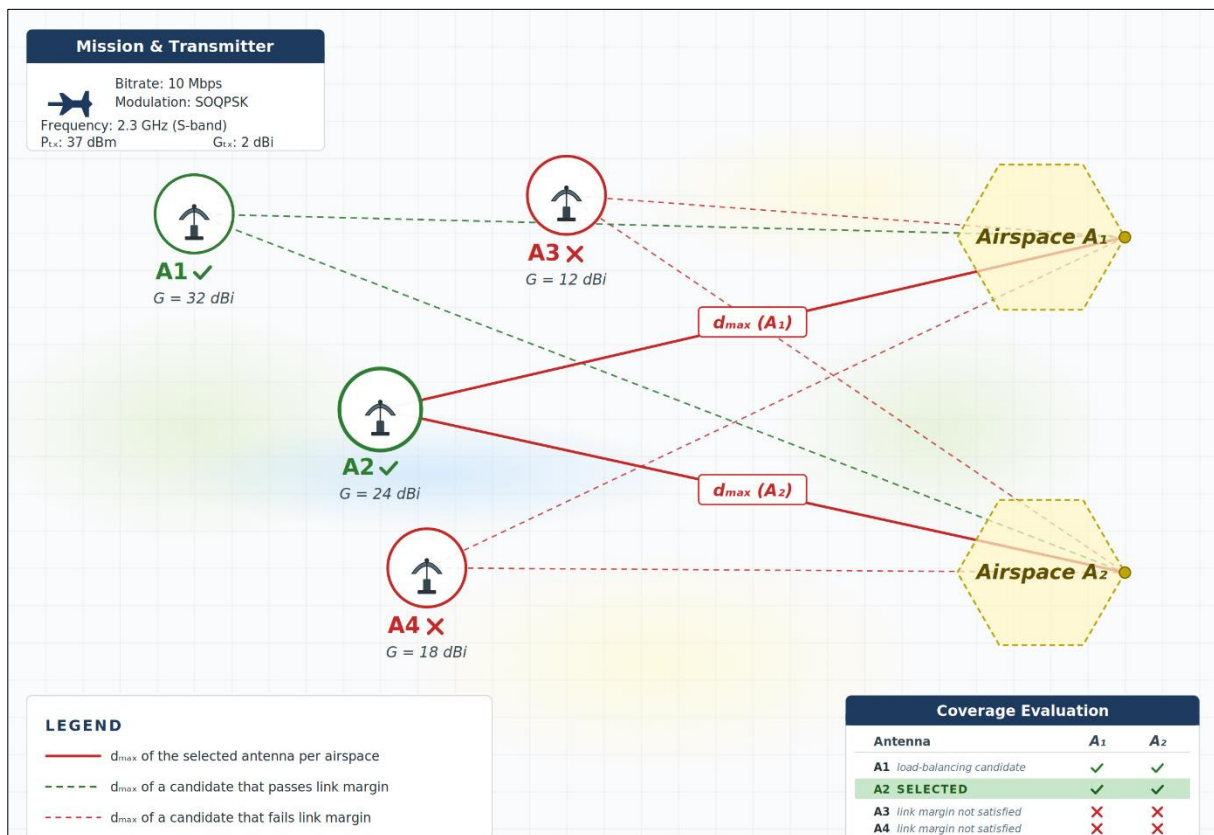


Fig. 11. Antenna Assignment for Multiple Airspace.

Frequency Allocation

Telemetry frequencies are among the most constrained resources managed by TULPAR. The S- and C-band segments are shared across all concurrent missions, and bitrate requirements

When multiple candidate antennas satisfy the feasibility condition for a given mission, the system applies a balanced allocation strategy to distribute workload evenly across the antenna pool rather than repeatedly selecting the same favorably located antennas. For missions with multiple operational airspaces as in the Fig. 11, the system selects an antenna that satisfies the feasibility condition for all of them, ensuring continuous coverage across the full mission area. If no candidate produces a non-negative margin, the mission is flagged for manual review. The antenna assignment is also re-evaluated automatically whenever mission parameters that affect coverage change — such as the operational airspace, flight schedule, or assigned FTMC — and the assignment is updated if a more suitable candidate becomes available. This approach ensures that antenna selection is not based on nominal proximity but on guaranteed worst-case link performance.

vary widely between platforms, leading to different bandwidth demands across the spectrum. Because a frequency conflict during execution can degrade link quality or interrupt data acquisition, conflict-free planning is a safety-critical requirement.

For each airborne transmitter, TULPAR jointly evaluates bandwidth requirement, hardware-compatible frequency band, candidate-frequency validity, and the spectrum occupancy of concurrent missions, while reserving a guard band on either side to prevent adjacent-channel interference. The allocation is also checked against known satellite pass intervals on the same telemetry bands. Fig. 12 summarizes these constraints.

Frequency Allocation Constraints	
Criterion	Description
Frequency band	S / C compatibility with transmitter hardware
Bandwidth requirement	Derived from bitrate and modulation type of the transmitter
Validity period	Time interval during which the candidate frequency is allowed to be used
Concurrent mission spectrum	Active transmissions within the mission's time window
Satellite pass intervals	External transmissions on the same bands
Guard band	Protection margin placed between adjacent assigned frequencies to prevent interference

Fig. 12. Telemetry Frequency Allocation Constraints

Once a conflict-free frequency is identified, it is allocated to the mission (Fig. 13) and reflected in the spectrum visualization, with any later parameter change triggering re-evaluation to maintain conflict-free status.

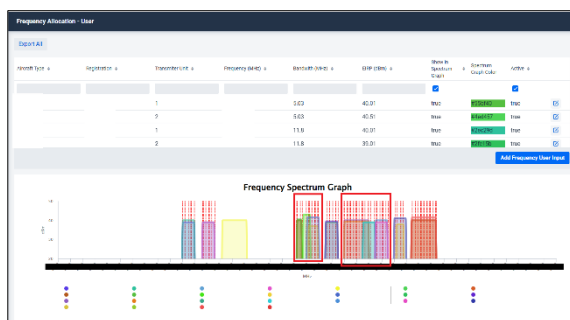


Fig. 13. Frequency Allocation and Spectrum Graph Screen.

Spectrum Management and Frequency Conflict Detection

While frequency allocation ensures conflict-free assignments at the time of planning, the dynamic nature of flight test operations — with activities being rescheduled, extended, or reassigned across the planning phase — requires continuous spectrum oversight throughout the planning lifecycle. This oversight is provided by two tightly coupled modules: the spectrum management module and the frequency conflict detection module, described in the following paragraphs.

In the spectrum management module, every assigned frequency is represented as an occupied interval, positioned according to its center frequency and extending across the bandwidth derived from the transmitter's bitrate and modulation [2]. Missions scheduled within the same time window are displayed

concurrently, allowing operators to observe the overall spectrum occupancy at a glance and identify densely used regions within each band. The visualization is updated whenever a new frequency is assigned or an existing mission parameter change. Fig. 14 illustrates a representative view of the spectrum dashboard, with concurrent frequency assignments and an automatically detected conflict highlighted.

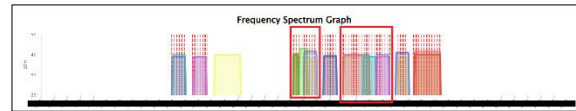


Fig. 14. Spectrum Management with detected frequency conflicts.

The frequency conflict detection module evaluates all frequency assignments active within the same time window and identifies overlaps between their occupied spectrum intervals. An overlap — whether due to proximity in center frequency or excessive bandwidth — is automatically flagged as a conflict. As illustrated in Fig. 15, three categories are distinguished: aircraft–aircraft conflicts, where two airborne missions compete for the same spectrum region; aircraft–satellite conflicts, where a scheduled mission overlaps with a known satellite pass interval on the same band; and aircraft–ammunition conflicts, where two external transmissions overlap during the planning phase.

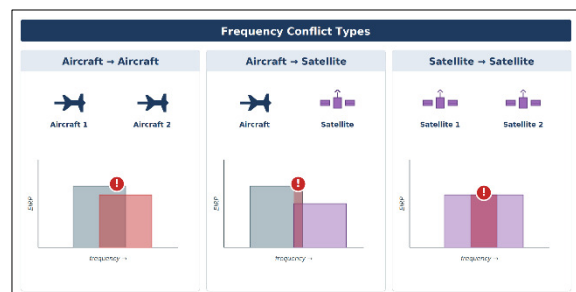


Fig. 15. Types of Frequency Conflicts in TULPAR.

Because satellite transmissions are not continuous but occur during known pass intervals, the spectrum management module also maintains a time-based view of satellite passes alongside the scheduled missions. This view, illustrated in Fig. 16, displays each mission's operational time window together with the pass intervals of the satellites relevant to the telemetry bands in use, and highlights any temporal overlap between a mission and a satellite pass that shares the same band. Planners can therefore anticipate satellite-induced interference intervals and adjust mission timing or frequency assignments accordingly.

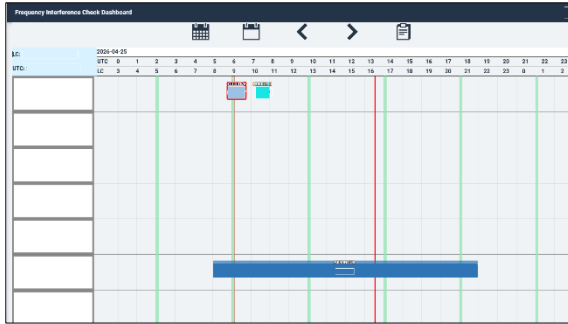


Fig. 16. Frequency Conflict Between Aircraft and Satellites.

In addition to the spectrum visualization and the satellite pass schedule, the system provides a dedicated conflict information screen that consolidates all detected frequency conflicts for a given planning day. For each conflict, the screen reports the time overlap of the participating entries in UTC, the identifier of each participant, the center frequency, and the occupied spectrum interval. An example is shown in Fig. 17. This consolidated view allows operators to review all conflicts in a single place and prioritize corrective actions based on the affected time windows and spectrum ranges.

Frekans Band Çıkışma Numarası	Frekans Çıkışması Mevcut Zaman Aralığı (UTC) - Frekans Çıkışması Mevcut Zaman Aralığı (L)	Frekans Çıkışması Mevcut Ürün	Frekans Çıkışması Mevcut Ürün Frekans Band Aralığı (MHz)	Frekans Çıkışması Mevcut Ürün Frekans Band Aralığı (MHz)
1	06:00-06:10 (UTC) 09:00-09:10 (L)			2370.00-2380.00 2371.07-2378.93

Fig. 17. Frequency Conflict Information Screen.

The detection logic is continuously applied to every frequency assignment and mission parameter change across the planning phase. Whenever an overlap is identified, the affected interval is highlighted on the spectrum dashboard and satellite pass schedule, a new record is appended to the conflict information screen, and an e-mail and SMS notification is dispatched to the relevant stakeholders. After corrective action — adjusting the frequency, shifting the mission time window, or reassigning resources — the detection process re-evaluates the modified plan to confirm that the conflict has been cleared. Fig. 18 summarizes this end-to-end flow.

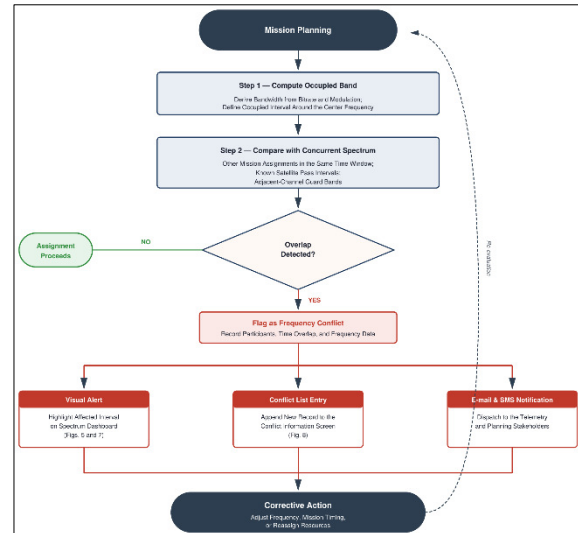


Fig. 15. Frequency Conflict Detection Flow.

Personnel Assignment For Telemetry Operations

In addition to FTMC, receiving antenna, and telemetry frequency assignments, the planning process also addresses the allocation of operational personnel required to support each mission. Personnel assignment is performed within the same system, drawing on the personnel records maintained in the definitions layer and on the activity schedule of each FTMC. The system ensures that personnel are allocated consistently with mission timing and role requirements, that assignments do not conflict across concurrent activities, and that the outcome is reflected in the overall planning state together with the other telemetry resources.

The personnel assignment process is executed via a background algorithm following the completion of activity planning within the FTMC, in accordance with the center's operational capacity, the periods defined in the definitions layer, and role requirements. The system incorporates three distinct allocation algorithms optimized according to the nature of the activity. The decision mechanism triggers the appropriate allocation algorithm by analyzing variables such as the type of aircraft or weekday/weekend parameters of the activity's start time. Upon finalization of the activity definition phase, the specific algorithm to be executed is determined automatically by this built-in decision mechanism. Personnel assignment dashboard screen is illustrated in Fig. 19.

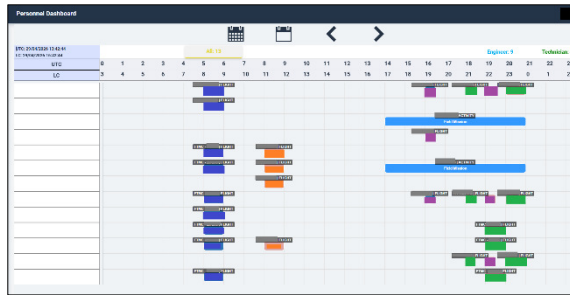


Fig. 19. Personnel Assignment Dashboard Screen.

To ensure operational efficiency, the following primary constraints are addressed within the allocation algorithm flow:

- **Activity Duration:** The projected total duration and the specific time slot of the mission.
- **Competence and Authorization:** The requirement for personnel to possess the requisite technical competence and operational authority for the assigned task.
- **Concurrent Task Conflicts:** Ensuring that the personnel to be assigned are not already allocated to a different, simultaneous activity.
- **Availability and Presence:** The duty status of the personnel, accounting for leave, rest periods, or other administrative constraints.

By performing the necessary filtering steps within the framework of these defined rule sets, the algorithm identifies which personnel will be assigned to which operational roles and finalizes the allocation process. Following the completion of the personnel assignment process, the system automatically triggers SMS and email notifications to the assigned personnel. The end-to-end personnel assignment flow is illustrated in Fig. 20.

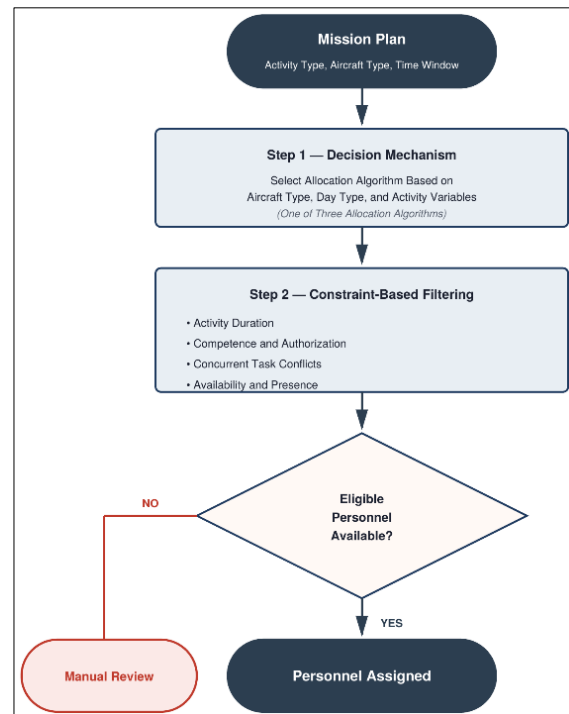


Fig. 20. Personnel Assignment Flow.

Results and Discussion

The increasing density of flight test operations makes the correct and consistent use of telemetry resources a central concern. Fig. 21 illustrates a typical daily planning view, in which multiple concurrent aircraft missions share a limited set of FTMCs, receiving antennas, and telemetry frequencies. TULPAR addresses this challenge through a centralized data model: all transmitter and receiver gains, antenna locations, and FTMC configurations are maintained in a single source, and resource assignments are performed automatically by evaluating link-budget, guard-band, and capacity constraints in a single pass. Aircraft frequency assignments are then easy to monitor through the spectrum visualization (Fig. 14) and the satellite pass schedule (Fig. 16), while any detected overlap is consolidated in the conflict information screen (Fig. 17) and triggers automatic notifications. The FTMC activity dashboard (Fig. 21) provides a complementary view of the resulting plan. The system enables rapid identification of spectrum conflicts and significantly reduces personnel dependency in resource allocation decisions under high mission density.

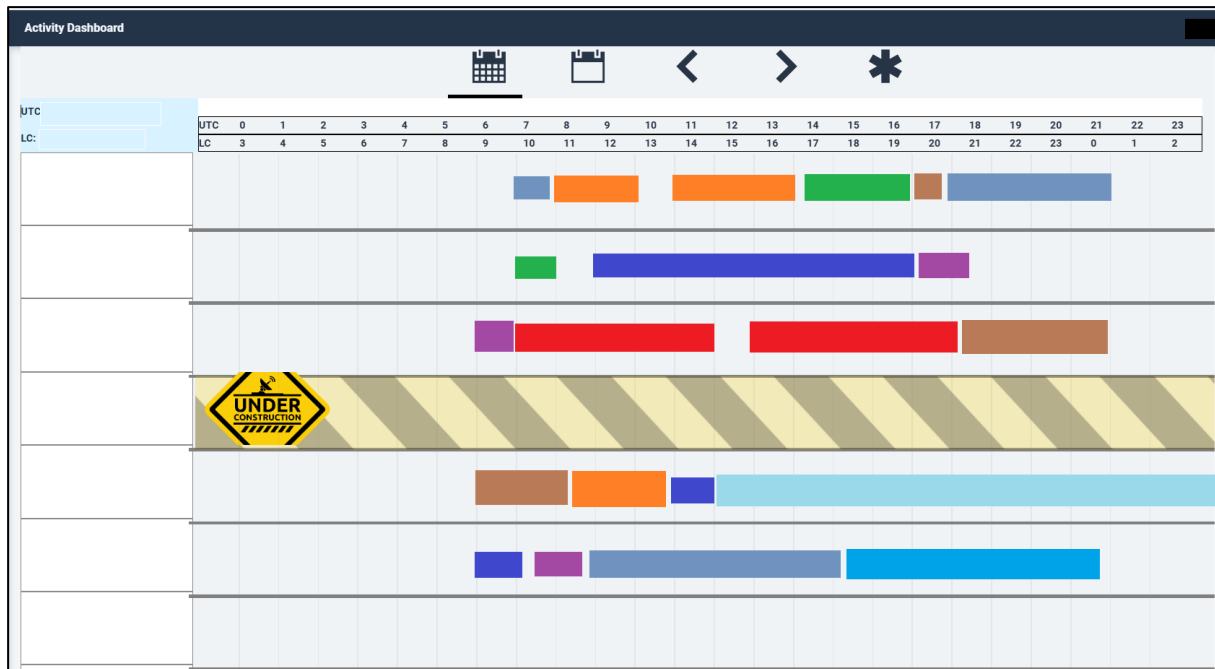


Fig. 21. FTMC Activity Dashboard.

Compared to manual planning practices, the proposed system enables consistent and repeatable resource allocation decisions, reduces the likelihood of frequency conflicts, and improves the overall utilization and optimization of limited telemetry infrastructure under high mission density.

The system also adapts automatically to intraday changes: when mission parameters are modified, only the affected resources are re-evaluated and the updated plan becomes consistent across all dashboards without manual re-entry. Future work will focus on integrating TULPAR with an in-house flight test data analysis platform developed at Turkish Aerospace, consolidating planning, execution, and analysis within a single connected environment.

Conclusion

This paper presented the telemetry resource management modules of TULPAR, the flight planning platform developed at Turkish Aerospace. The system coordinates FTMC, receiving antenna, telemetry frequency, and personnel assignments within a single workflow, maintains an interactive spectrum visualization, and provides automated detection of frequency conflicts between concurrent missions and satellite passes. The representative test scenario demonstrated that the system supports conflict-free planning of multiple concurrent missions, enables dynamic re-planning in response to intraday changes, and reduces the coordination burden that would otherwise be handled through manual cross-checking.

References

- [1] TULPAR Flight Planning and Management System — User Manual, Turkish Aerospace Industries, 2025. (internal document).
- [2] IRIG Standard 106, "Telemetry Standards," Range Commanders Council, Telemetry Group. Available at <https://www.irig106.org>.