A Case Study of the Application of Model Based Systems Engineering to a UAS

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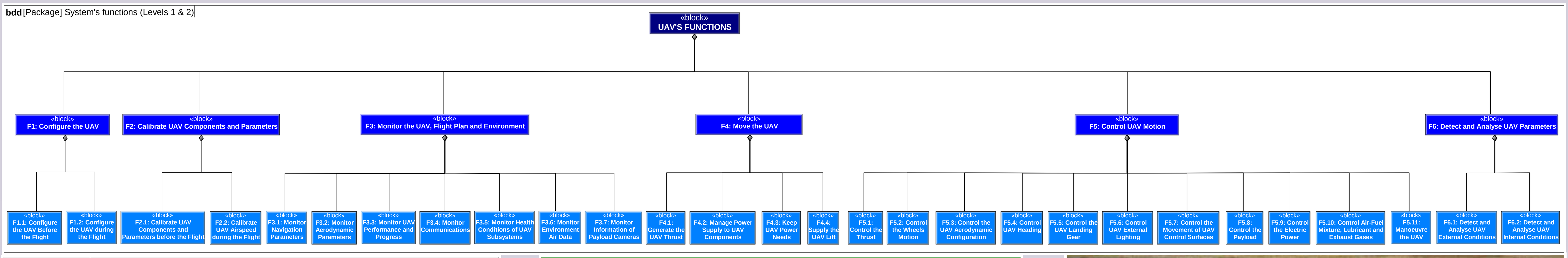

Diagram 1: Functional Breakdown Structure

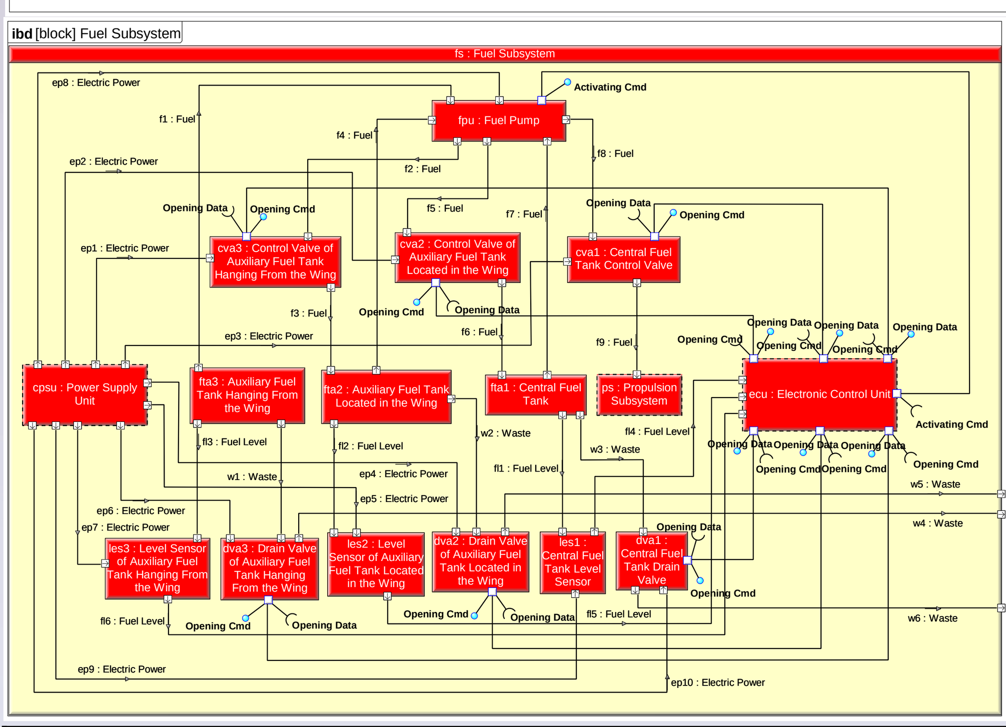

Diagram 2: Fuel Subsystem IBD Diagram

Figure 1: UAV K2A Manufactured By Unmanned Solutions

Table 1: N² Chart of Level-1 Functions

Information to UAV Operator 1*. Communication Ports Checking Signal to Payload Operator and UAV Subsystems.	Changes to Calibrate Sensors*. Changes to Calibrate Alarms*.	Navigation Data*. Aerodynamic Data*. Performance and Progress Data 1*. Data Monitored on Communications*. Information about Subsystems Conditions*. Environment Air Data 1*. Information Sampling Frequency of Cameras*. Radio Frequency Signal Received by Transponder and Sent by ATC. UAV Identificator.	Information about Desired UAV Speeds*. Firing Command of Devices*. Shutdown Command of Devices*. Information Saved in UAV Data Storage Device 1*. UAV's Weight.	Information about Landing Gear Position*. Brake Pressure. Actions Ordered UAV on Ground*. Runway Heading. Non-coordinated Movements of Turn Manoeuvres*. Valves Opening Data 2*. Information to UAV Operator 2*. Information to Payload Operator*. Information about Camera Subsystem*. Information Saved in UAV Data Storage Device 2*.	Information about Taxiing Speed. Brake Pressure*. Aerodrome Coordinates*. Elevation of Surface Points*. Lift Coefficient Depending on the Angle of Attack*. Drag Coefficient Depending on the Angle of Attack*.	
F1 CONFIGURE THE UAV	Notification about UAV Magnitudes Enabled.	Notification about UAV Magnitudes Enabled. Notification about Chronometer Enabled. Height and Pressure Height References Chosen. Automatic Flight Path Selected. Automatic Flight Path Updates 1*. Positioning Coordinate System Chosen.	Notification about UAV Magnitudes Enabled.	Notification about UAV Magnitudes Enabled. Chosen Action to Do After Completing the Automatic Flight Path. Automatic Flight Path*. Automatic Flight Path Updates 1*. Mode of Operation Chosen*. Parameters for Observation a Surface Point*. Runway Coordinates. Positioning Coordinate System Chosen.	Height and Pressure Height References Chosen. Notification about UAV Magnitudes and Automatic Actions Enabled*. Automatic Flight Path*. Automatic Flight Path Updates 2*. Information about the Mode of Operation*. Deflection Command of Control Surfaces Due to the Weight*. Runway Features 2*. Positioning Coordinate System Chosen.	Checking Signal to Control Communication Ports Operation*. Fuel Valve Opening Data*. Fuel Pump Activating Command*. Runway Features 1*.
Permission to Use the Magnetic Compass during the Flight. Permission to Use the GPS during the Flight. Permission to Use the Altimeter during the Flight. Permission to Use the Directional Gyro during the Flight.	**F2** CALIBRATE UAV COMPONENTS AND PARAMETERS	Notification about UAV Sensors Enabled*. Notification about UAV Alarms Enabled*.	Notification about Autopilot Failure Alarm Enabled. True Air Speed (TAS).	True Air Speed (TAS).	True Air Speed (TAS).	Sensors' Values to UAV Operator*. True Air Speed (TAS).
Fuel Level of UAV Fuel Tanks*. Remaining Distance to the Next Waypoint. UAV Height Monitored. UAV Heading Monitored. UAV Coordinates Monitored.	Indicated Air Speed (IAS). Environment Air Temperature. Aerodynamic Data Monitored*.	**F3** MONITOR THE UAV, FLIGHT PLAN AND ENVIRONMENT	Climbing Speed Monitored. Measuring Instrument Failure Alarm Signal*. Alarm Signal due to Wrong or Non-received Indications*. Angle of Attack Monitored. Fuel Level of UAV Fuel Tanks*. Motor Power Consumption Monitored.	Navigation Data Monitored 1*. Aerodynamic Data Monitored*. Signal of UAV Subsystem Wrong Configuration 2*. Changes in Air Speed Monitored. Fuel Level of UAV Fuel Tanks*. Activation of Safe Mode of Operation. Motor Power Consumption Monitored.	Navigation Data Monitored 2*. Measuring Instrument Failure Alarm Signal*. Alarm Signal due to Wrong or Non-received Indications*. Angle of Attack Monitored*. Environment Air Data 2*. Activation of Safe Mode of Operation. UAV Mission Time. Motor Power Consumption Monitored.	Clock Signal to Get Sensors's Data Monitored. Alarm Signal*. Signal of 'Information Received'*. Signal of UAV Subsystem Incorrect Configuration 1*. Information Saved in UAV Data Storage Device*. UAV Information to ATC*. Payload Cameras Data. Performance and Progress Data 2*.
UAV Total Weight.			**F4** MOVE THE UAV	Valves Opening Data*. UAV Lift. UAV Total Weight. Deflection Command of Control Surfaces*.		Valves Opening Data*. Electric Power to Devices*. UAV Lift. Deflection Command of Control Surfaces*.
		Processed Data of Payload Cameras*. Deflection Command of Rudder Due to Motor Thrust Asymmetry.	Firing Command of Pumps*. Shutdown Command of Devices*. Command to Change the Motor Power Consumption*.	**F5** CONTROL UAV MOTION	Deflection Command of Control Surfaces*. Parameters to Calculate UAV Heading*.	Control of Reverse Thrust Caused*. Stoppage of UAV Subsystem Wrong Configuration*. Deflection Command of Control Surfaces*. Front Wheel Turn*. Break Pressure Control on Rear Wheels*. UAV Speeds*. Orthoimage Generated. Information to UAV Subsystems*.
Waypoint Arrival Recognition.	Dynamic Pressure Calculated. Waypoint Arrival Recognition.	Command to Change the Roll Angle*. Command to Change the Pitch Angle*. Command to Change the Yaw Angle*. Remaining Distance to the Next Waypoint. Distance to the Aerodrome.	Dynamic Pressure Calculated. Air Density Calculated. Relative Air Speed.	Information about Best Gliding Angle Calculated. Waypoint Arrival Recognition. Command to Change the Roll Angle*. Command to Change the Pitch Angle*. Command to Change the Yaw Angle*. Navigation Data Calculated*. Break Pressure Rate Calculated*. State of UAV Height*. Desired UAV Height.	**F6** DETECT AND ANALYSE UAV PARAMETERS	UAV Relative Position to the Aerodrome. UAV Relative Position to the Next Waypoint. Notation of UAV Faults and Failures*.

Systems Engineering Process

The goal of this student project is to use a combination of well-known Systems Engineering best practices and modelling by means of SysML notation for the engineering of the K2B UAS (*Unmanned Aircraft System*) used for generic civil missions. A former member of the K2 family is shown in Figure 1.

The Systems Engineering community describes the Systems Engineering process as an iterative approach to technical management, acquisition and supply, system design, product realization, and technical evaluation at each level of the system, beginning at the top and propagating them through a series of steps, which eventually lead to a preferred system solution.

The aim of functional analysis is to create a functional architecture that is the input for defining the physical architecture through the allocation of functions to the system components.

Large systems are often made up of subsystems that are logically and physically partitioned into parts or components. Aggregation allows us to consider the thing as a unit, ignoring its parts, a simplification in thought. Alternatively, hierarchy lets us consider a component as an assembly of parts to think how it is built.

The Systems Engineering process used here has three main steps: (1) Defining the UAV operational concepts; (2) Modelling the UAV functional architecture; (3) Modelling the UAV physical architecture.

The operational concepts are described by 14 operational scenarios using the Use Cases modelling technique and complemented with a state diagram describing the main operational states of the UAV. Some of the operational scenarios identified are Starting the UAV, turn manoeuvre, automatic flight path execution, and landing manoeuvre.

The UAV functional architecture, displayed in Diagram 1, represents a hierarchical view of the UAV capabilities without considering the implementation solution. Here the SysML block diagram is used to describe the UAV functional hierarchy. A five-level block hierarchy identifying more than 130 UAV functions was produced. These hierarchical diagrams are complemented with a N² chart, Table 1, to represent the main functional interfaces.

The physical architecture shows the main UAV subsystems, their interfaces and their internal parts represented as blocks in SysML. Here, for illustrative purposes, the UAV fuel system is shown in Diagram 2.

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