Re-Designing the Auto-Throttle system using MBSE

Souparno Sengupta
Chandana Panda
Ankit Raj Mathur

Problem Statement

- Modern day pilots have more supervisory roles in the cockpit compared to flying responsibilities due to advanced automation

- Heavy reliance on automation often leads pilots to make mistakes or fail to pre-empt dangerous situations (including taking back control from automation)

- Prolonged and continuous use of automation makes pilots lose their flying skills

Our Solution

- Automation is essential in modern aeroplanes, however degree of automation needs to be optimized to bring the pilot into the functional loop

- We desire to develop such automation philosophy which keeps the pilot more involved in flying and aids in retaining their flying skills

- In this paper, we have re-designed the human machine interaction of the auto-throttle system to illustrate our automation philosophy while retaining the core functionality of auto-throttle system

Key Highlights of our Automation Philosophy

- Our philosophy is aimed at greater human involvement in a routine manner
- Bridge the gap between procedures to be followed during automated flight and manual flying
- Develop involuntary responses within pilots which leads them to take command of aircraft controls in dire situations rather than trying to debug the problem

Overview of Autothrottle

- An automated system that allows to attain and maintain specific speed or thrust settings by automatically modulating the throttle settings

- Modes of operation:-
  - *Speed Mode:* Auto throttle computer modulates the engine thrust to attain and maintain the target speed

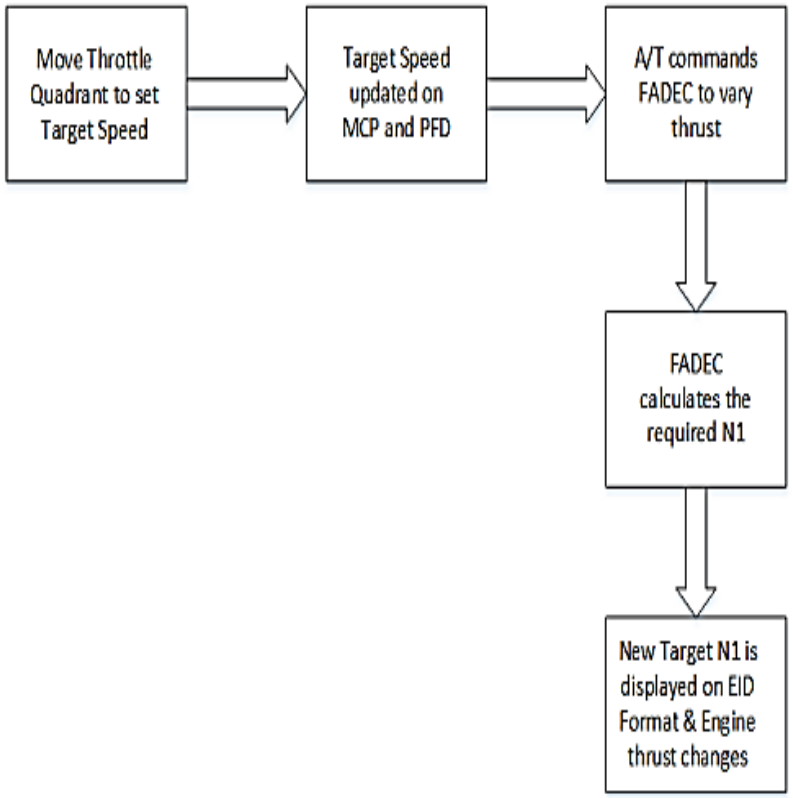
  - *Thrust Mode:* Auto throttle computer modulates the engine thrust to attain and maintain a specific thrust setting as per phase of flight (eg. climb thrust, descent thrust etc)

Pilot interaction with the current AT system

- Pilot interacts with the current Auto-Throttle (AT) system using the switches on the Flight Control Panel
- The buttons highlighted by the red box control the inputs to the auto-throttle system
- The N1 and SPEED button is used to select the parameter that the pilot wishes to control via the auto-throttle system
- The rotary knob is used to set the target speed/N1

Auto-Throttle with Our Philosophy

Pilot will provide inputs to the auto throttle computer using the throttle levers instead of the rotary knobs on the MCP



AT Engagement/Disengagement: Push button located on TQA. To prevent inadvertent thrust at time of disengagement, throttles will be moved to position consistent with current supplied thrust. Pilot can override this movement by moving the throttle manually

Setting Target Speed: Target speed will be set by moving the throttles. For higher target speed, move forward. For lower target speed, pull back

Indications: As throttle position is varied

- Target speed readout on MCP changes
- Target N1 (as per target speed) will appear on EID
- As speed is achieved, target N1 required to sustain the speed will be displayed
- As target N1 is attained, target N1 display will be removed

Tool Used

- We are using Matlab Simulink to develop requirement models for auto-throttle system based on our new automation philosophy

- In the following slides, we have converted auto-throttle system requirements (in textual format) to flowcharts and then to Simulink models

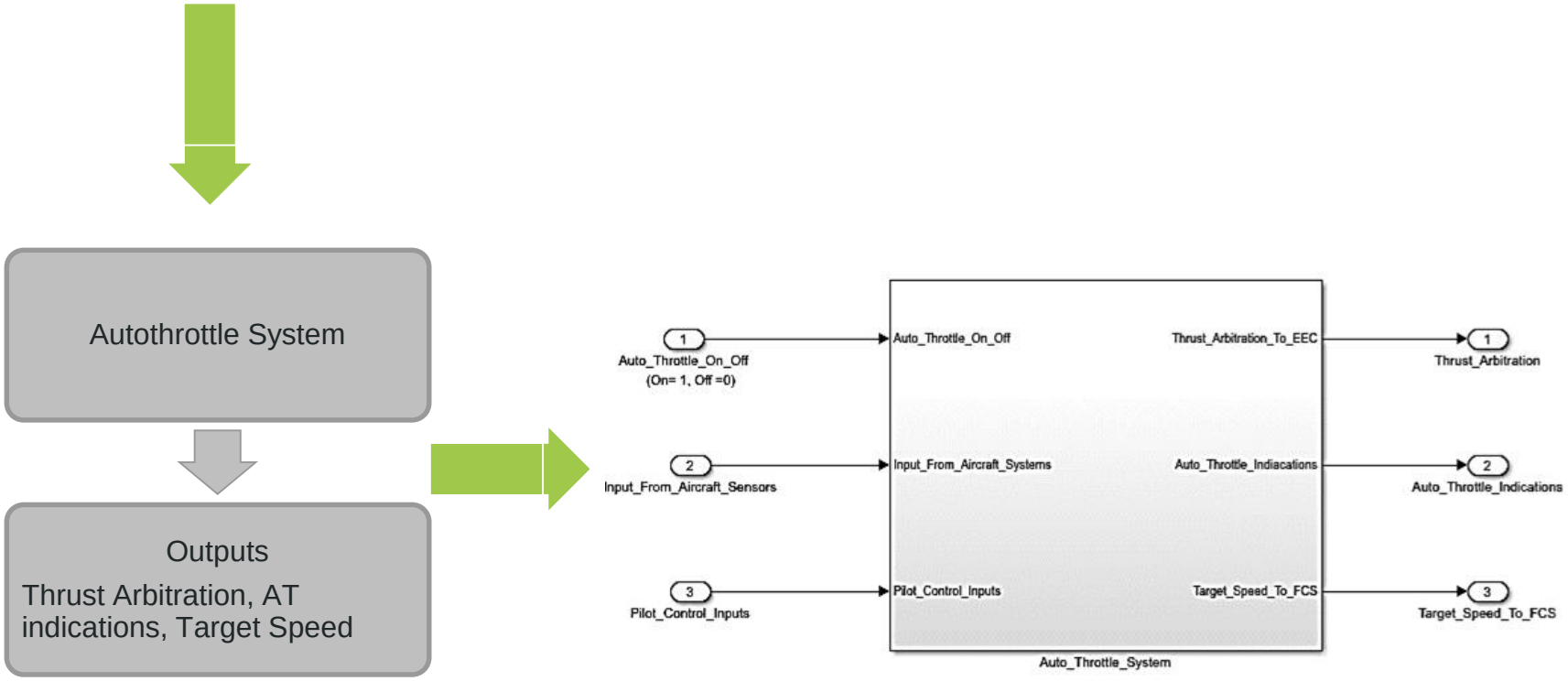
Model Based Systems Engineering

"MBSE" is the formalized application of modelling to support system requirements, design, analysis, verification and validation activities beginning in the conceptual design phase and continuing throughout development and later life cycle phases"

INCOSE SE Vision 2020 (INCOSE-TP-004-02, Sep 2007)

Example of Req Models for New Auto-Throttle System

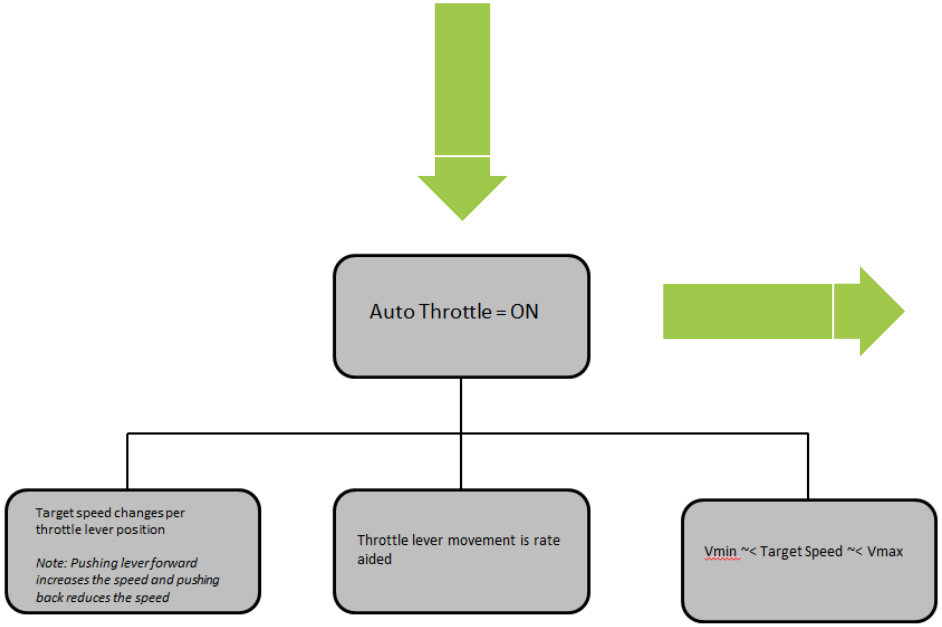
L0_1: The Auto-throttle system shall provide thrust arbitration function and associated indications

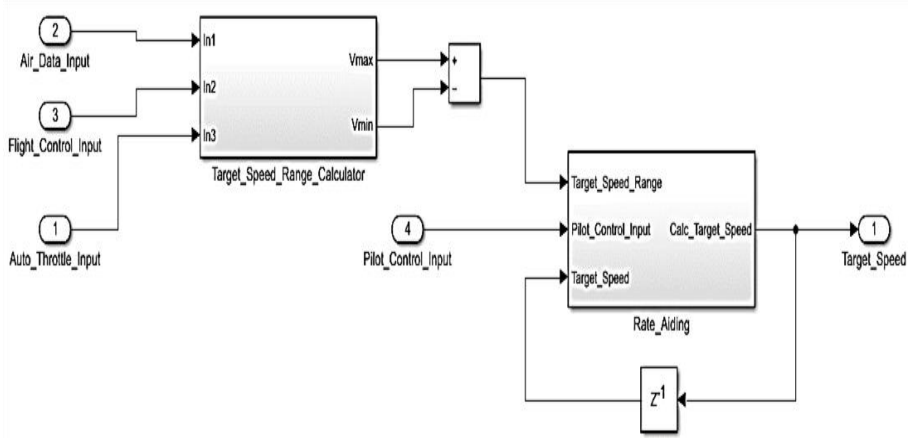


Note: The flow charts are the model representation for high level textual requirements. The Simulink models are representation of lower lever requirement derived from the high level requirement model

Example of Req Models for New Auto-Throttle System

L1_3: The system shall provide for setting of the target speed using the throttle levers on the Throttle Quadrant Assembly when Auto Throttle is engaged
L1_4: The throttle lever movement shall be rate aided when the Auto Throttle is engaged
L1_5: The settable range of the target airspeed shall be dynamic and shall lie between Vmax and Vmin

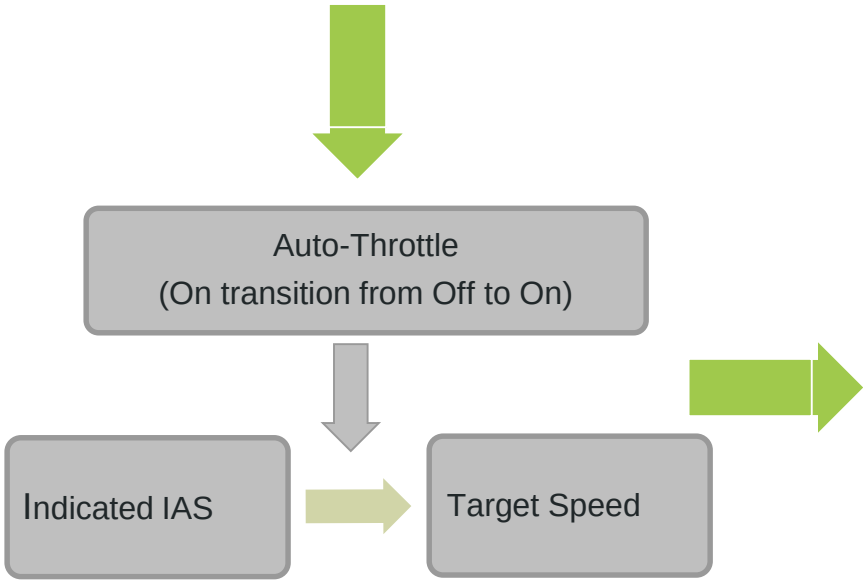


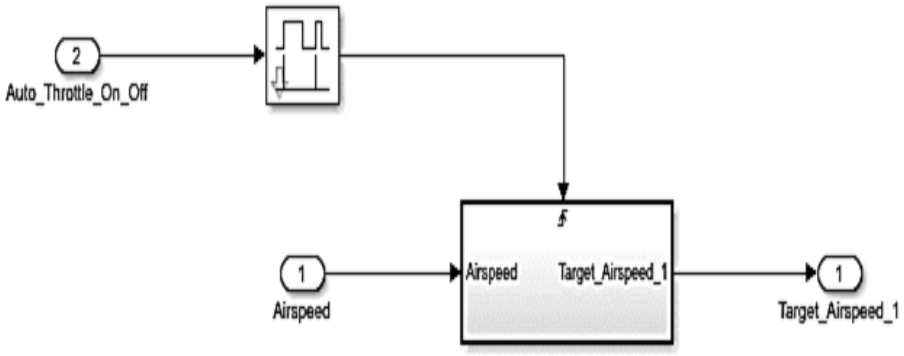


Note: The flow charts are the model representation for high level textual requirements. The simulink models are representation of lower lever requirement derived from the high level requirement model

Example of Req Models for New Auto-Throttle System

L1_7: Upon auto-throttle engagement target airspeed shall be set to current IAS

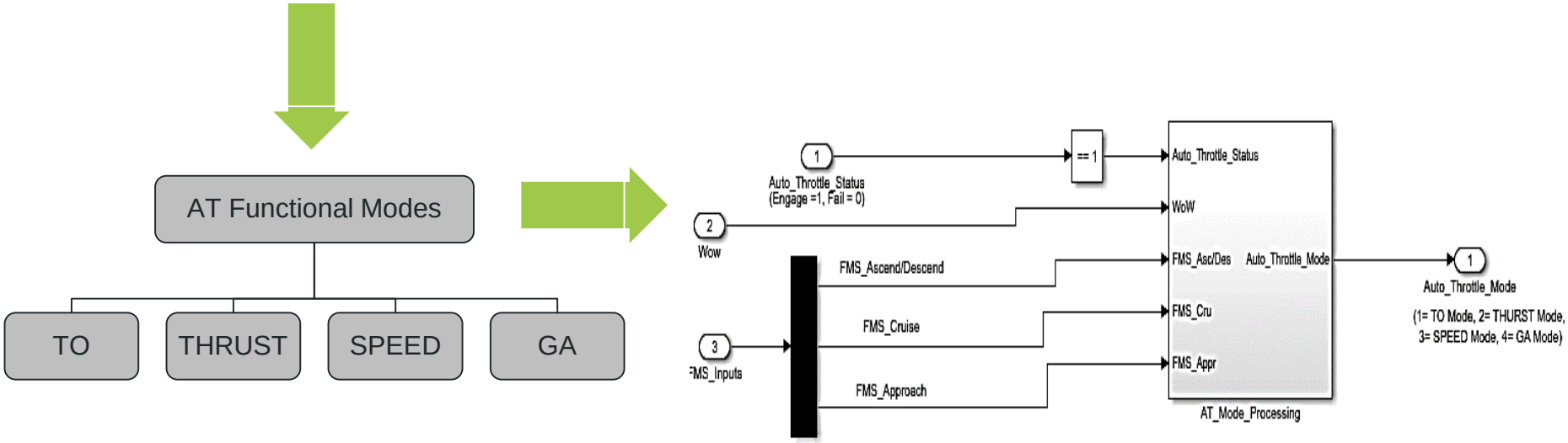




Note: The flow charts are the model representation for high level textual requirements. The simulink models are representation of lower lever requirement derived from the high level requirement model

Example of Req Models for New Auto-Throttle System

L1_2: The Auto-throttle system shall have the following functional modes- TO, THURST, SPEED, GA



Note: The flow charts are the model representation for high level textual requirements. The simulink models are representation of lower lever requirement derived from the high level requirements model

Reference

- Automation in Modern Airplanes - A Safety and Human Factors Based Study by Souparno Sengupta, Anantha Krishna Donekal and Ankit Raj Mathur [http://onlinelibrary.wiley.com/doi/10.1002/j.2334-5837.2016.00339.x/full]

- Airline Pilot's Perception of Advanced Flight Deck Automation by Prevendren Naidoo

- Accident investigation summary of Turkish Airlines flt 1951 [http://aviation-safety.net/database/record.php?id=20090225-0]

- Introduction To Model-Based System Engineering (MBSE) and SyML – by Laura E. Hart; Presented at the Delaware Valley INCOSE Chapter Meeting, July 30, 2015 [https://www.incose.org/docs/default-source/delaware-valley/mbse-overview-incose-30-july-2015.pdf]