FLOWNEX®
SIMULATION ENVIRONMENT

RE-ENGINING OF A MIRAGE F1 FIGHTER

Re-engining of a Mirage F1 Fighter required modification of the existing aircraft refueling system. Aerosud used Flownex to; Predict flow rates and refueling sequences in the system. Investigations of valve failure cases were also performed with Flownex to ensure that for any single failure case, the system would remain safe.

AVIATION INDUSTRY

CUSTOMER PROFILE:

Aerosud is a diversified civil and military aviation engineering company. Its services include design, development, prototyping and in service support of aircraft systems for major international aviation companies.

Aerosud manufactures around 2000 parts and assemblies a day and supplies these to the assembly lines of Airbus, Boeing, BAE Systems, Agusta Westland Helicopters and Spirit AeroSystems.

CHALLENGE:

A contract which involved the re-engining of a Mirage F1 Fighter with a Klimov RD33 engine used in the Mirage 29 Fighter. Part of the re-engineering required modification of the existing aircraft refueling system. Aerosud required; Prediction of flow rates and refueling sequences in the system, Investigation of valve failure cases to ensure that for any single failure case, the system would remain safe.

BENEFITS: Flownex provided the following benefits:

- Simulation of the complete operation of the fuel system and early detection of operational & commissioning issues.
- The re-fueling sequence of the tanks could be optimized to increase the speed of refueling and improve pilot safety and capital investment protection.
- Possibility to test multiple re-fueling and valve failure cases.
- Graphical representation of the dynamic refueling sequence.

SOLUTION:

The model was used to size tank restrictors and obtain the required flow rates. Refueling rates were determined to be within the specified envelope. Critical analyses of failure cases were performed. Tank pressures were predicted and vent-lines were analyzed at various flow rates to ensure that the aircraft fuel system remains safe and the centre-of-gravity (cg) position of the aircraft remained centered. Aerosud confirmed results predicted by Flownex® with ground test results.

"Flownex® enabled engineers to analyze the complete fuel system and its components in an efficient and accurate way, providing them with piece of mind that the final system design is safe, reliable and conforms to customer requirements."

Aerosud

AERIAL REFUELING

INTRODUCTION

Aerosud, a South African aviation company, had a major contract which involved the re-engining of a Mirage F1 Fighter with a Klimov RD33 engine used in the Mirage 29 Fighter. Part of the re-engineering required modification of the existing aircraft refueling system. A contract-specified minimum refueling time resulted in a need for pressure refueling. As with commercial aircraft, the fundamental need for pressure refueling of a military aircraft is to provide safe, quick aircraft deployment. There were other safety issues that needed to be considered in the refueling system of a military aircraft. The fuel system needs to be safely isolated in case of an unsuccessful attempt at in-flight refueling. Failure of a refueling system to shutoff can result in hazardous fuel spillage and/or tank over-pressurization which could lead to the loss of an aircraft and/or lives.

Figure 1: Example of a fighter plane undergoing aerial refueling.

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Fuel transfer is typically controlled by shutoff valves with associated orifices to control the flow rates into the tanks. These orifices have to be sized appropriately to allow refueling in the required time frame as well as ensuring that the refueling sequence is such that the aircraft centre-of-gravity (CG) limits are maintained.

CHALLENGES

Aerosud needed to:

- Predict flow rates and refueling sequences in the system,
- Investigate valve failure cases and ensure that for any single failure case, the system would remain safe.

BACKGROUND

Aerial refueling, also called **in-flight refueling** is the process of transferring fuel from one aircraft (the tanker) to another (the receiver) during flight. The procedure allows the receiving aircraft to remain airborne longer, extending its range or loiter time on station. Because the receiver aircraft can be topped up with extra fuel in the air, air refueling can allow a take-off with a greater payload which could be weapons, cargo or personnel: the maximum take-off weight is maintained by carrying less fuel and topping up once airborne. Alternatively, a shorter take-off roll can be achieved because take-off can be at a lighter weight before refueling once airborne.

The F1 fighter has a number of tanks, as shown in Figure 2. Due to the minimum refueling time required, a pressure refueling system, in which multiple tanks are refueled simultaneously, was selected over a traditional method in which the tanks are refueled individually. Pressure refueling provides a safe, quick aircraft turn-around-time. Typical refueling pressures are 35 ~ 55 psig (2.41 ~ 3.79 bar g). Based on this operational requirement, it was deemed necessary by Aerosud to model the fuel system.

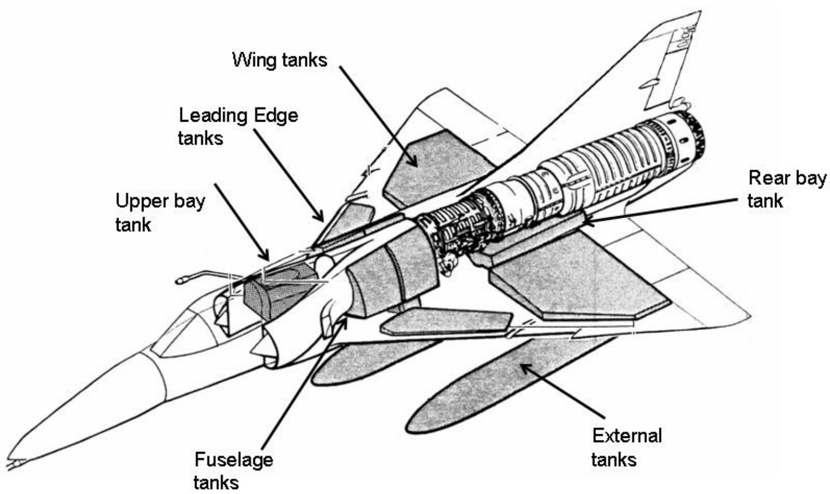

Figure 2: Positions of the fuel tanks.

Figure 3 shows the cheetah fuel system and tank location used on the fighter plane.

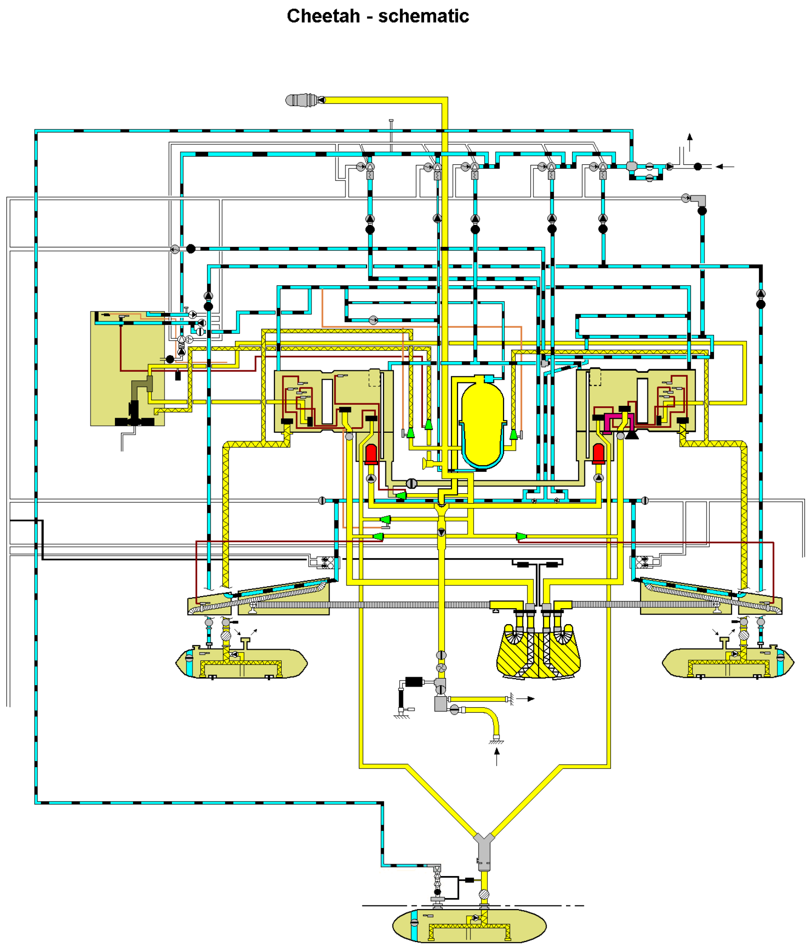

Figure 3: A schematic of the Cheetah fuel system used.

The blue lines are the venting / pressurization system, and the yellow lines are the fuel transfer/refuel system. Each tank group consists of its own refuel and transfer valve. Transfer valves are controlled by its associated float valves in each tank group.

SOLUTION

Aerosud modeled the aircraft fuel system in Flownex®.

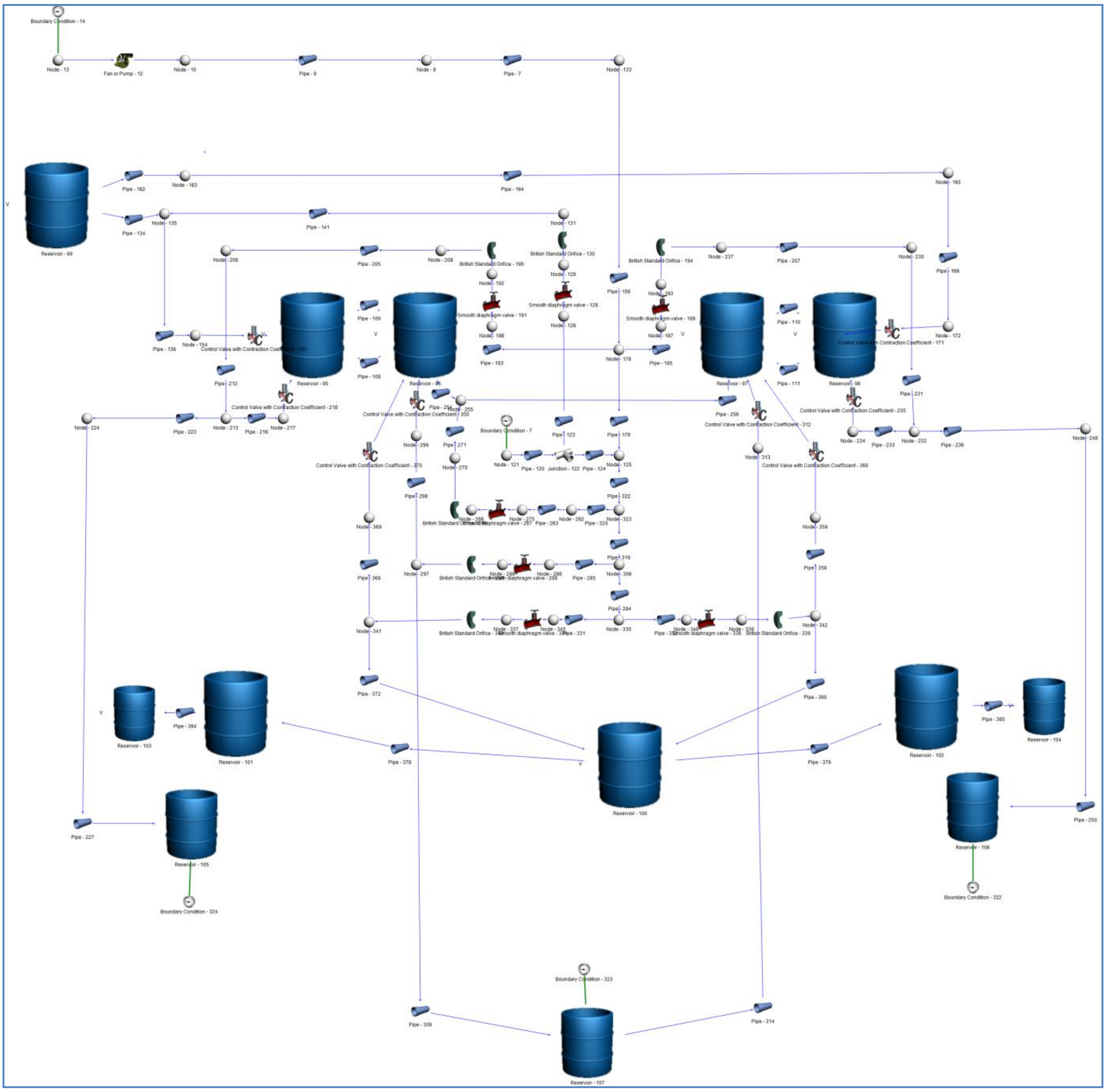

Figure 4: Flownex® model of the refueling system.

The refueling system model depicted in Figure 4 is interlinked to the venting system model in Figure 5. This was necessary to model the backpressure of the air being vented out of the fuel tanks and its effect on the refueling sequence and rate. Transient refueling operations of the system as well as valve failure cases were simulated.

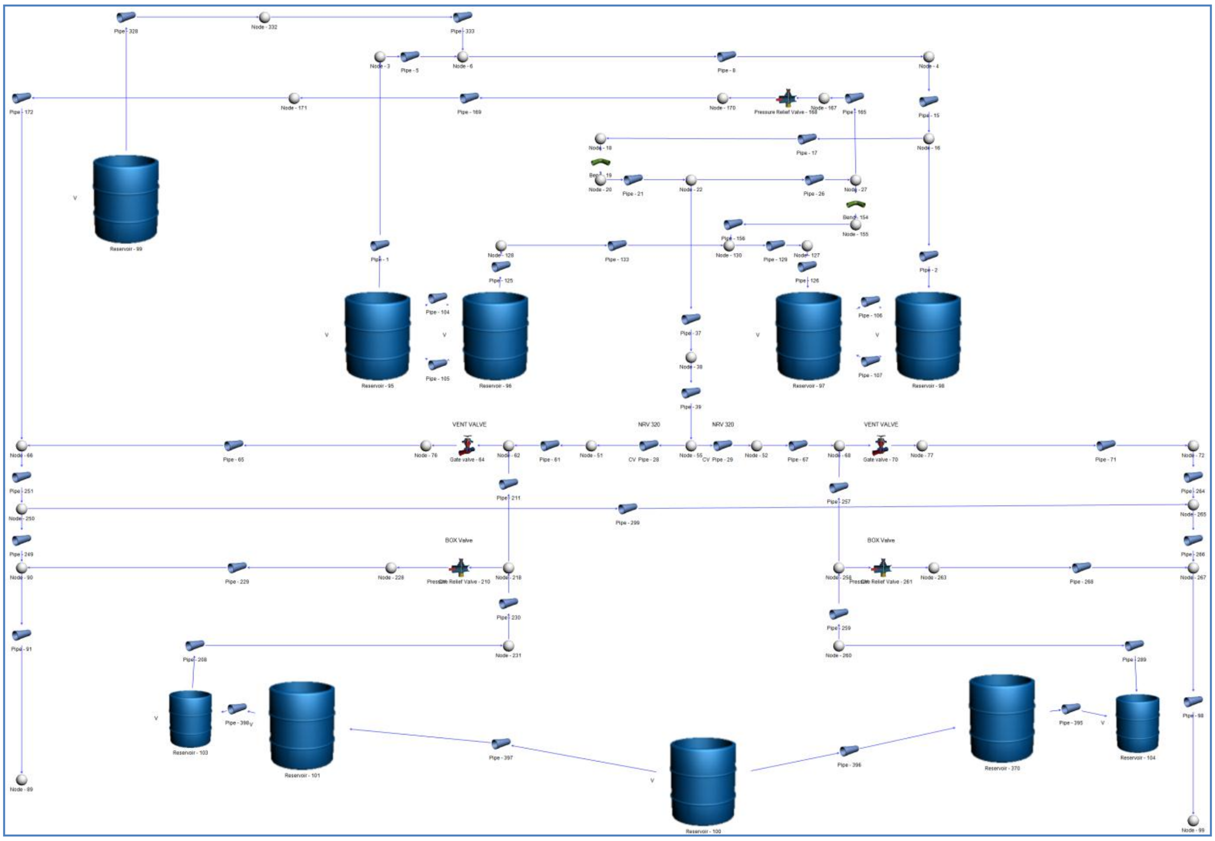

Figure 5: Flownex® model of the venting system.

The benefits of using Flownex® for the simulation were:

- A Human User Interface (HMI) to simplify the use of the constructed model and to help with visual interpretation of results could be developed. See Figure 6 and Figure 8.
- Pressure in the different tanks could be displayed graphically during the refueling sequence to identify possible operational issues and to determine the maximum pressure operational envelope. See Figure 7.
- The piping data could be obtained from the built-in pipe schedule tables to speed up the creation time of the model. This allowed the engineering team to spend more time in evaluating and improving the results of the design changes.
- Full operation of the fuel system could be simulated. Thus commissioning and operational issues could be detected early and rectified even before the actual ground and eventually air refueling commissioning. This greatly reduced commissioning time and saved Aerosud precious time & money.

- The re-fueling sequence of the tanks could be optimized to increase the speed of refueling and improve pilot safety and capital investment protection.
- The adequacy of the venting/pressurization system was also tested.
- Several re-fueling and valve failure cases could be saved as scenarios within the model, which can be re-called at any time for further simulations and refinements.

"Aerosud was able to corroborate the results predicted by Flownex® with results from ground tests "

RESULTS AND SUMMARY

Flownex® provided adequate information on the fuel system which assisted the engineers during the design and development phase with reasonable accuracy. The model was used to size the restrictors to the tanks in order to obtain the required flow rates. Refueling times were also determined to be within specified minimum times. The critical analysis of failure cases was performed. Tank pressures were predicted and vent-lines were analyzed at various flow rates. This was to ensure that the aircraft fuel system remains safe and the centre-of-gravity (cg) position of the aircraft remains in the centre. Aerosud was able to corroborate the results predicted by Flownex® with results from ground tests.

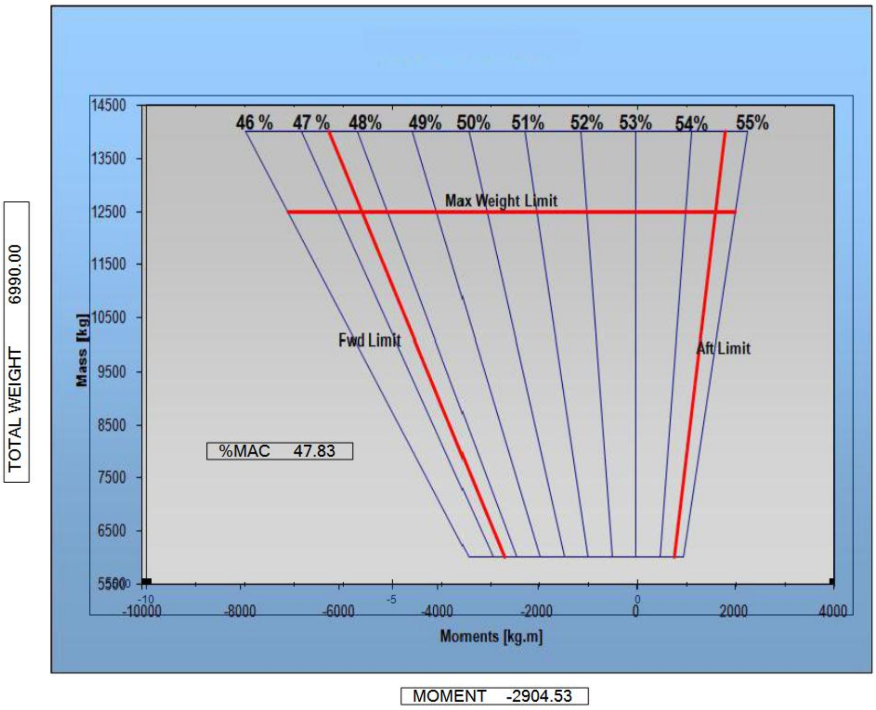

Figure 6: Determination of Aircraft centre-of-gravity.

Changing a restrictor size influences flow rate into a particular tank, which in turn will influence the centre-of-gravity (cg) position of the aircraft. Thus the need to model the change in cg position as the tanks fill.

Figure 7 and Figure 8 show tools available within Flownex® to display results. An HMI was developed to display the tank levels and flow rates and the tanks pressures could be shown on a graph.

The pressure spikes in Figure 7 caused by the opening and closing valves were also observed on transient ground tests

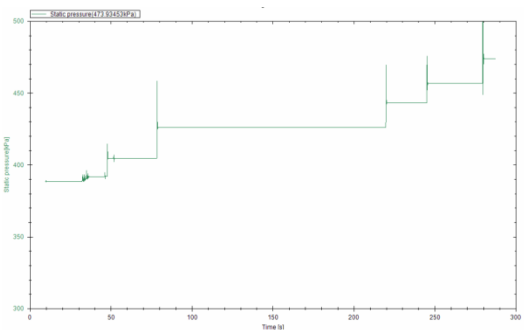

Figure 7: Graphical display of external tank's pressure.

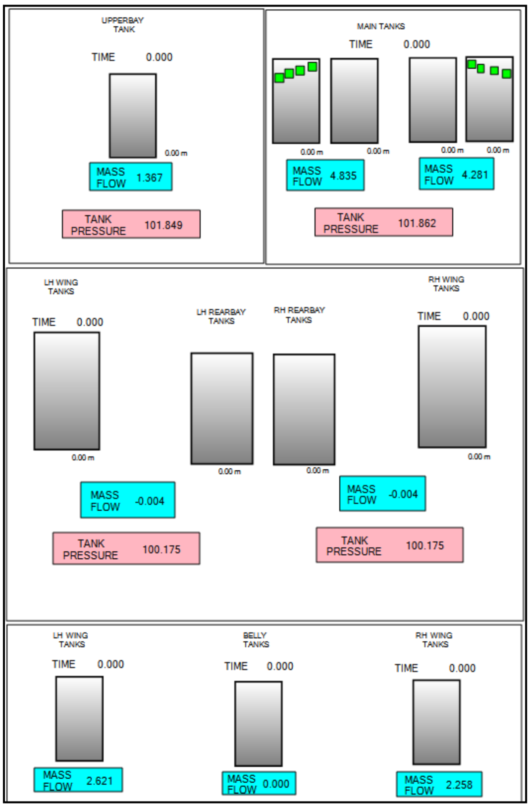

Figure 8: HMI to display the tank levels and flow rates.

COMPANY PROFILE

Aerosud was formed in 1990 by the then key designers of the South African Rooivalk Combat Support Helicopter, together with similar leaders from the Cheetah fighter program (Mirage III upgrade) and the Product Support Environment. It has since grown into a diversified civil and military aviation engineering company. Its services include design, development, prototyping and in service support of aircraft systems.

AEROSUD
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