Description

Tu-154 is a mid-range civil jet aircraft. It made it's maiden flight in 1968, and the aircraft has been operated for commercial flights since 1972 till now. In total more than 900 hulls were built, with modifications. It was the first aircraft created by Tupolev Design Bureau entirely for civilian needs, without using an existing bomber design as the blueprint.

For a long time the aircraft prevailed in USSR civilian aviation. It brought civilian aviation of that time to a modern level. Speed, power, comfort and impressive looks helped TU-154B to find favor with passengers. With that stringent flight envelope demanded significant improvements in pilot training. Unfortunately, pilot mistakes caused accidents and crashes - 63 aircraft were lost.

In our days aircraft is heavily used and even still produced. Latest craft (model M) has been assembled in 2006. 3 more hulls are on order till 2011. But low fuel efficiency probably will compel airlines to discontinue the orders, and the more ancient B modification is scheduled to be put out of service in 2010.

The plane did not leave virtual aviation enthusiasts cold. There are several Tu-154 models for MSFS, but the best in visual, dynamic and systems modeling is the freeware one called PT Tu-154-B2 by the Project Tupolev team. Attention to detail, complex and realistic systems, controls and navigation equipment which allow to use model as a teaching aid for students made PT Tu-154-B2 loved by simmers worldwide.

FlightGear flight simulator already has a Tu-154 model. It seems like PT team has had a hand in making this model because Denis Okan is mentioned among it's authors. Sadly, the model is not finished and seems to be abandoned since 2006. Mistakes in dynamics and lack of essential panels make it impossible to get any reasonable impression about the aircraft.

After discussion with the PT team in 2007 the process of porting original Project Tupolev Tu-154-B2 model to FlightGear was started. Authors gave visual model (sources), textures and sounds as well as permissions to modify and redistribute them (in accordance with the freeware license, see end user terms at http://fs-proteam.com/products.html?op=one&pw_patt=catalog&id=18).

Sadly, systems and dynamics well developed by PT team cannot be used with FlightGear - the platforms differ too much. That is why porting the model to FG required recreating almost everything from scratch. There is not a single line of code left in from original PT, only textures, models and sounds remain.

Roman Skoryh, author of original visual model of Tu-154B for Project Tupolev, gave permission for distribution of this model under GPL license.

Since version 3.0, released at june 2013, Tu-154b for FlightGear is distributed under GPL.

Model controls

A joystick is highly recommended for flight control. Besides general axes (stick, rudder, throttle) an additional axis for spoilers is recommended. Also it is possible to use several throttle axes for separate engines. We recommend to use a joystick with fixed idle and MCT (max continuous thrust) detents.

Also, view-hat configured for looking around the virtual cabin is a requirement. It is advisable to use some key to center view quickly. Pitch trim is used constantly and we recommend to use two buttons for it. Rudder and roll trim is seldom used and there is no point assigning joystick buttons for these.

If you have free joystick buttons left, you can use them for differential braking. If you want to use a dedicated axis for nosewheel steering only you will have to change model's XML config.

You must bind the weapon control to *fire trigger* on you joystick if it is not bound so default. A script controls.trigger(0) should be assigned to the fire button (usually, button 0). The trigger is used for otto disconnect. If you have diff brakes on it, they only get used on the ground anyway. These functions will not interfere with each other.

For your convience, you can turn AP to "stab" mode (wing level and pitch hold) by key *d*, autothrottle – by key *Shift+d*. Disconnect AP and AT – by pressing *Ctrl+D.*

Press *Shift+N* to set "nominal" (MCT) thrust, *n* – for 0.85 of MCT, *Ctrl+N* – for 0.7 of MCT. Press F2 to engage thrust reversers on engines 1 and 3.

A wheel mouse is strongly recommended for model control. There are many controls, knobs and switches which can be operated with the mouse wheel, and it's much more convenient than clicking. Usually, all mouse areas are highlighted with yellow boxes when you press *Control+C*, but if the active area is a 3D object, it will be highlighted grey, which is easy to miss.

Model is only ever flown from the virtual cockpit, there are no 2D panels. Virtual cockpits often have problems with access to distant controls – that's why we made our best to provide easy access to controls and easy navigation through them in Tu-154. Most noticeable is the powerful FG Views system which allows active virtual cockpit use. I will use the *View* term when referring to the point of view.

There are five preset views in the cockpit:

- Captain's view - press *1*
- Copilot's view - press *2*
- Navigator's view (center pedestal) - press *3*
- Overhead - press *4*
- Flight engineer's console - press *5*

It is possible to use default shortcuts to change views (*V*, *Shift+V*, *Ctrl+V*) but it is not really convenient since you have to cycle through external views as well. We use the numeric keys because our model is made for soft throttle control and does not need the standard FG throttle detents

In this manual all controls are labeled with numbers and the first digit represents view number. So, if there is reference to switch number 406, you should look for this switch at view 4 (overhead view in this case).

The sim saves each view's state so it is important to have a key for neutral view position.

Besides five virtual cockpit views there is an additional sub-view. What is it and what is it used for? Imagine you are landing the aircraft. You have to switch views from instruments to the window and back quickly. It is not a big problem in reality but quite an issue in the sim. Usually, instruments are badly readable and changing FOV to zoom them reduces ground visibility.

Sub-views solve this problem. Sub-view is a set of fixed additional views, that can be activated with button ~ (tilde, leftmost key in the digits row). After the button is released, previous view is restored. Sub-view parameters (direction and FOV) can be changed the usual way, but unlike ordinary views sub-view do not save state after you switch to another view. Default sub-views are preset for:

- captain and copilot - enlarged instruments panel view (the big three)
- navigator - central instruments panel view (course and ADF needles, UShDB and USh)
- overhead view - enlarged PU-11 panel view

- flight engineer - left part of the console

You can change default sub-views parameters in the model's set-file to fit your wide screen.

Also, depending on selected view, some objects are hidden. For instance, the navigator's view hides the thrust levers to let you see UShDB and USh.

Captain's panel

Fig.1. Captain panel

101 - Flight Director Indicator (PKP)

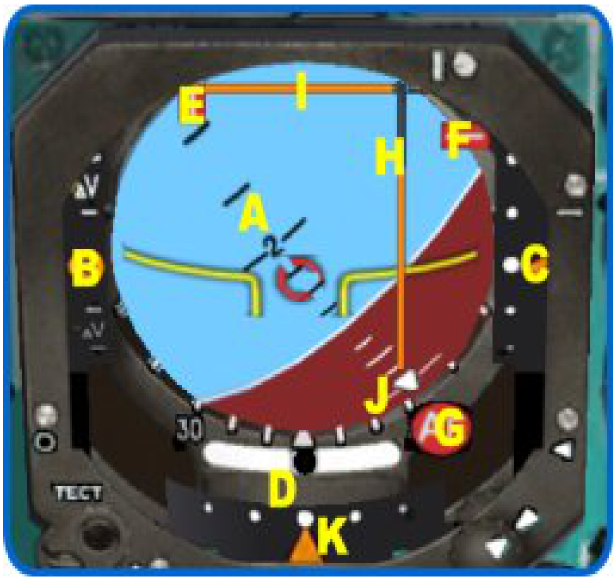

Fig.2. PKP (FDI).

A - Artificial horizon

B - "Fast/slow" indicator - index bug moving up means that the speed is higher than the commanded AT speed

C - Glideslope index

D - Sideslip indicator

E - Localizer flag (visible when no or nav mode is selected and being received by the radios)

F - GS flag (visible when no glideslope is received or the FD is not engaged)

G - Vertical gyro failure flag (flag is raised when the gyro is not aligned)

H - course director arrow

I - glidepath director arrow

J - Bank angle

K - Localizer index

102 - Horizontal Situation Indicator (PNP)

Fig. 3. PNP (HSI).

A – range scale. Not wired and not used Tu-154

B – Heading handle

C – Precise course display

D – Course handle

E - Compass scale. Can show the magnetic or gyro headings, depending on the switch on the overhead

F – Course needle

G – Deviation needle. Shows aircraft deviation from path in various NAV modes (ILS, VOR, NVU)

H - Glidepath needle

I - Glidepath ILS flag (visible when no glideslope is received)

J - Localizer ILS flag (visible when no loc signal is received)

K – TKS compass system flag (visible when the system is inop)

L – Heading bug (ZK)

M - Mode Indicator (SP-VOR-NVU)

N – Drift angle scale. Rolling index shows the drift angle, measured by the DISS (doppler radar) equipment.

103 - AOA and G-meter (AUASP)

104 - Rate-of-climb indicator VAR-30

105 - Barometric altimeter. Click the lower right knob to set the pressure

106 - Radio Magnetic indicator IKU-1 , controlled from the compass system TKS-1 and Course system Kurs-MP-2.

107 - DME indicator IDR-1 (DME/RSBN)

108 - Indicated airspeed indicator US-I-6. The red index refers to commanded speeds for the AT system. With Autothrottle switched off, the index is slaved to the airspeed needle

109 - Machmeter UM-1, fed from the SVS system (static pressure system)

110 - Vertical Velocity Indicator VAR-75

111 - AChS-2 clock, additional controls (like the timer) are not implemented

113 - Combined Speed Indicator KUS

114 - Outside air temperature indicator TNV-15

115 - Standby artificial horizon AGR

116 - Radio altimeter RV-5M. Mouse area in lower right allows to set DH altitude for "H" light and the "decide" alert (indicated by the yellow bug)

117 - Altimeter UVID-15, indication in feet. This device is electric and uncoupled from the SVS (static air pressure) system.

118 - Altimeter VM-15, SVS dependent on the SVS

119 - Warning light test button

120 - Source selector for the IDR-1 (DME). It differs a bit from the real plane. In the real plane the indicators are independent and have their own panels for different frequencies. The Kurs-MP system is the Russian equivalent to VOR navigation and has been added for international flights. The switch toggles between DME-1, DME-2 and RSBN.

121-123 - Hydraulic systems 1-3 low pressure warning lights

124 - Emergency brake system low pressure warning light

125-127 - Hydraulic systems 1-3 pressure gages

128 - Emergency brake system pressure gage

129 - ЗАХОД Localizer Mode. ABSU stabilizes landing course using ILS selected on the left KURS-MP set

130 - ЗК Heading Select Mode. ABSU stabilizes course selected using ZK bug (see HSI, mark D).

131 - Bank Stabilization Mode. ABSU keeps constant bank

132 - NVU mode. ABSU intercepts and maintains track using NVU nav signals

133 - VOR mode. ABSU stabilizes course using VOR nav signals

134 - Marker I (outer marker). Flashes while passing the outer marker

135 - Marker II (middle marker). Flashes while passing the middle marker

136 - Bank Control Unit BKK-18 failure

137 - ГЛИСС Glideslope mode. ABSU keeps the glideslope using the ILS nav signal

138 - Autothrottle. Autothrottle is engaged

139 - Pitch Hold". ABSU stabilizes pitch

140 - Altitude Hold Mode (H). ABSU holds altitude using pitch

141 - IAS Mode (V). ABSU uses "speed on pitch"

142 - MACH Mode (M). ABSU uses "mach speed on pitch"

143 - Marker III (Inner Marker) - not used

144 - Fuel Below 2500 KG Warning

145 - AOA Warning (stall)

146 - G Overstress Warning

147 - Lights up when the transponder is set to "hijack" (not used the sim)

148 - Lights up if Cabin Crew sends a hijack signal (not used in the sim)

149 - Overspeed Warning

150 - Left bank angle warning (33 or 15 degrees in landing config)

151 - TOGA engaged. ABSU goes around automatically

152 - Below decision height H indicator

153 - Terrain warning

154 - Right bank angle warning (33 or 15 degrees in landing config)

155 - Not in takeoff config. Flashes if takeoff procedures are not completed, namely:

- Flight control boosters are not enabled
- Nosewheel steering hyrdaulic actuator is not engaged
- Nosewheel steering set to 63 deg instead of 10
- Spoilers are extended
- Flaps are retracted

156 - "Void" pitch trim, MET Failure or MET has come to a stop or an attempt is detected to operate pitch trim during Autopilot operation. The trim input will be ignored in this case since the SAU (autopilot) latches on to the trim

157 - Autopilot (ABSU) - bank control failure (not implemented)

158 - Autopilot (ABSU) - pitch control failure (not implemented)

159 - Automatic TOGA failure (not implemented)

160 - Landing mode autopilot failure or glideslope deviation too big

161 - Autothrottle Control Failure - "throttle" warning (not implemented)

162 - Maximum Localizer Deviation exceeded

163 - Glideslope Deviation below 100m until DH if plane is 1 dot above glidepath

164 - Engine FIRE (not implemented)

Overhead

Fig. 4. Overhead.

401 - AUASP system power (Angle of attack vanes and indication, G meter)

402 - AUASP check - not used in the model

403 - UVID-15 altimeter power

404 - AGR standby ADI power

405 - Clears BKK error signal and flags on the ADI

406 - BKK vertical gyro power

407 - ABSU/SAU power (autopilot and flight director)

408, 409 - Attitude gyros ADI (PKP) captain and copilot power

410 - Standby attitude gyro power

411, 412 - Lateral TKS gyros power

413 - Switch lateral gyro heating. Not implemented

414, 415 - Mag course correction switches

416, 417 - Switch HSI - gyro or gyro-mag corrected heading, captain and copilot

418, 420 - Static pressure SVS check button and heat switch. Not implemented

419 - Static pressure SVS system power

421, 422 - KURS-MP nav radios power, left and right

423 - RSBN nav system power

424 - RSBN "Ident" mode switch. Since this mode is hardly ever to be implemented in FG, in the model this switch *toggles RSBN to the VOR mode*

425, 426 - RV-5M Radio altimeter power. Only the captain's radio altimeter works in the model

427, 428 - COM radios power

429, 430 - ADF radios power

431, 432 - CB for roll correction of the lateral gyro. Since the simulator does not implement gyro drift, these switches are not utilized. Perhaps one day the gyro drift will be implemented...

433 - Doppler drift and ground speed measurement system (DISS) power

434 - "land-sea" Doppler switch

435 - the "Diss-SVS-check" whether the NVU will be driven by the Doppler system or the static air pressure system alone. When NVU is on SVS uncoupled from the DISS you will need to compute and enter the wind drift yourself.

436 - PU-11 TKS (lateral gyro) control panel

Fig. 5. PU-11 TKS compass system.

A - Latitude input

B - Automatically adjust latitude while flying. Not present on the real aircraft. However, in the model it is possible to engage this feature. Keep on "РУЧН" (manual) for more realism. Before flying the descent you will need to adjust the latitude to your destination.

C - Switch the correction mode of the TKS. AK AK (astrocorrection) on real aircraft is not implemented. MK corrects the gyros to the magnetic heading, GPK uses the internal gyro heading.

D - Latitude adjustment knob

E - switch the driving gyro TKS output from the main to the auxiliary gyro and back

F - Manual gyro adjustment

G - switch the gyro used for correction from the main to the auxiliary gyro and back

H - Quick alignment button

I, J - Main and aux gyro unit failure lamps

437 - Passenger signs "Exit", "No smoking, fasten safety belts." No idea where you can make them in the model. Not implemented.

438 - RSBN control panel. In RSBN mode, the left handle switches tens, right one - ones (of the channel number). If RSBN works in compatibility mode with VOR, the left knob sets megahertz, right - kilohertz. In this mode, there is a tooltip for the frequency. The "RSBN-VOR" is possible only in the model, in terms of realism the use of this mode is not recommended

439 - Transponder. Implemented since ver.3.0. Work under FG ver.2.10 and newest. It support skawk mode A, C, Standby mode (selector to B) and Ground mode (selector to D).

440, 441 - COM radios. There are hotspots for fequencies. Right handle control sound volume.

442, 443 - ADF radios. The switch on the top selects the "active-standby" frequency, the selected frequency is highlighted with a green lamp on top. The left ADF is 1, right one is 2. There are hotspots for control sound.

444 - Pitot heat switch. As far as I know, the effects of pitot icing are not modeled in FG

445, 446 - KURS-MP nav radio. The indicator on the left switches the bearing (not the indicator on the HSI!), the right controls the frequency. Hotspots are availaible at the top and at the bottom of each digit. There are hotspots for control sound.

447 - Nosewheel steering hydraulics switch

448 - Nosewheel steering angle limit (63 or 10 degrees)

449 - Landing lights extend-retract switch

450 - Landing light mode tri-pos switch - landing, off and taxi

451 - Flaps lever

452 - Gear lever

453 - Switch the USHDB needles from ADF to VOR and back

Center panel

Fig. 6. Center panel.

301 - Manual stabilizer control switch. To operate, open cap and press the switch underneath - switch towards you is pitch up, switch away from you is pitch down

302 - Auto stabilizer preset

303-305 - Engine failure lamps

306-308 - Engine N2 RPM indicators

309 - Elevator/stabilizer indication. In the center of the device there is a hotspot for hints on the current weight, CG position, Vr and Vref. The values of velocities are computed for the current configuration

310 - Flaps indicator, left and right

311 - Gear lamps

312 - Turn coordinator EUP

313 - Placard "Stab working". Illuminates when the stabilizer is moving

314, 315 - Placard "Flaps I","Flaps II". Illuminates when the flaps left and right are moving (the model always moves flaps in sync)

316, 319 - Placard "middle" Illuminates when the middle (in-flight) spoilers are extended

317, 318 - Placard "inner" Illuminates when the inner spoilers are extended (only possible when the gear struts are compressed after touchdown)

320 - Groundspeed indicator USVPK. In the "air" mode shows the airspeed using the static air pressure system(SVS), in a "ground" mode - ground speed from the DISS equipment. At the bottom of the device there is a hotspot for mode selection

321 - Range-azimuth indicator PPDA-Sh used by the RSBN set

322 - Captain-copilot heading bug switch (the selected bug is used by the autopilot)

323, 324 - Spring loader placards. In this model, both boards are always on, the system of loaders is not implemented

325-327 - "Trim neutral" placards. Also function as hotspots to reset trims to neutral

328 - Status of RA-56 hydraulic flight control actuators. The needles will move when the autopilot operates the controls

329 - Placard "NVU failure". Failures not implemented

330 - Placard "Failure of reserve MGVK".

331 - Placard "NVU-VOR Automatic." Illuminates when the NVU nav computer fails or when the VOR signal used by the NVU is no longer received. Failure is not implemented

332 - Placard "Correction on". Illuminates when the NVU is being updated from an RSBN beacon

333, 334 - Placard "Range autonomous","Azimuth autonomous" Lights up when the RSBN signal is lost

335 - Placard "DISS mem". Lights when the DISS system is inop

336 - Placard "Change ChO" Lights up before passing an NVU waypoint

337 - USh navigator instrument. Arrow with a plane shows the main gyro heading from TKS, movable triangular index - position of the aux gyro. Deviation arrow under the airplane arrow shows the drift angle, measured by the DISS

338 - UShDB indicator. While the ADF arrow indicates the angle of the NDB, the VOR mode, the opposite end of the arrow shows the current radial. VOR-ADF switch is on the overhead, and the instrument is not slaved (rotate the compass scale using the knob on the right)

339 - Lid of the hydraulic flight control booster switches. Before take-off booster switches should be and the lid closed

340 - "Map angle" Instrument NVU updates. There are hotspots right and left of two mobile scales. The upper scale introduces tens of degrees, lower - ones

341 - Switch nav lights

342 - Switch beacon lights

343 - Switch instrument lights on. Lights go on throughout the cabin, including the flight engineer panel

344 - Placard "Slats moving". In this model slat management is slaved to the flaps, separate slat extension is not implemented

Console

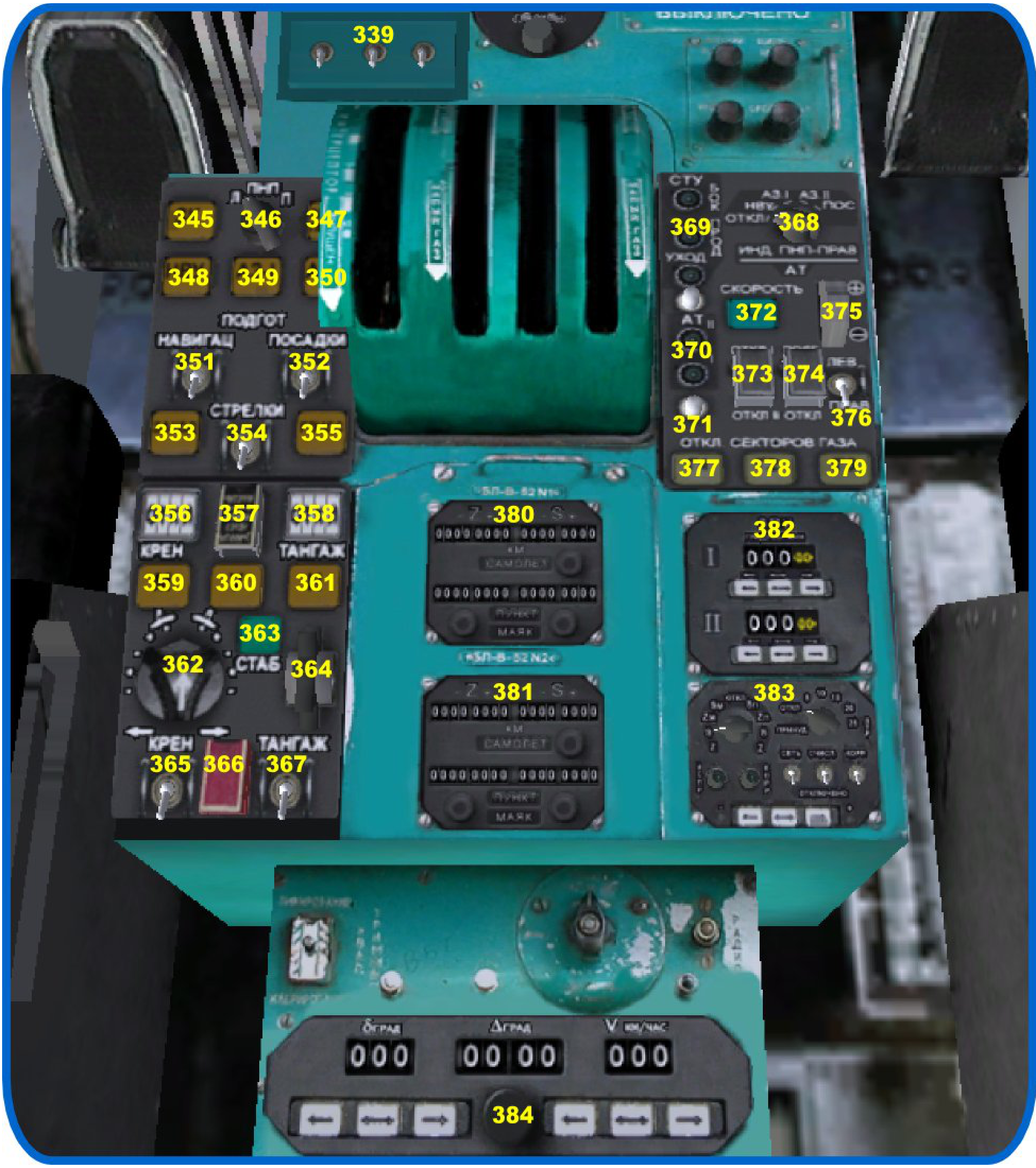

Fig. 7. Center pedestal.

345 - Button-lamp "ZK" Autopilot heading mode, by HSI heading

346 - "L-PNP-R" selector. In VOR mode, switches the source of bearing fed to the autopilot from the left HSI to the right one

347 - Button-lamp "Prog Reset". Resets the autopilot to pitch and bank stab modes

348 - Button-lamp "NVU" Couples the NVU nav computer to the HSI and the autopilot

349, 350 - Button-lamp "AZ-I", "AZ-II". Couples the HSI and the autopilot to the left or to the right KURS-MP nav radio set

351 - Nav needles mode (use KURS-MP as VOR receiver)

352 - Land needles mode (use KURS-MP as ILS source)

353 - Button-lamp "ЗАХОД" (localizer). Couples the autopilot bank to the ILS signal of the *left* KURS-MP set

354 - Flight director needles (vertical needle only available when GS is alive and GLISS mode is on)

355 - Button-lamp "ГЛИСС" (glideslope). Couples the autopilot pitch to the glideslope on the *left* KURS-MP set

356 - Indication "Aitopilot on/off" in bank

357 - Covered button for vertical gyro alignment

358 - Indication "Aitopilot on/off" in pitch

359 - Button-lamp "M". Mach on pitch mode

360 - Button-lamp "V". Speed on pitch mode

361 - Button-lamp "H". Alt capture and hold mode

362 - Autopilot turn wheel

363 - Button-lamp "Stab". Engage or disengage the autopilot coupling (when disengaged only the flight director will stay operative). When engaged initially will enable bank hold and pitch hold.

364 - Pitch wheel

365 - Couple the bank channel steering or use the flight director

366 - Turbulence switch. Will toggle the steering on the autopilot to work in coarser flight control deflections

367 - Couple the pitch channel steering or use the flight director

368 - Feed the autopilot from the left or the right HSI

369 - Lamps "computers ready" - bank, pitch stability, go-around.

370 - Lamps "autothrottle ready"

371 - AT check. Not implemented in the model

372 - Button-lamp AT speed hold (will hold the speed currently indicated)

373 - AT power switch

374 - AT "armed" indication

375 - AT speed control wheel - up is faster

376 - Switch the AT speed control bug from the left to the right airspeed indicator. In the model the captain's indicator is always used

377-379 - button-lamps declutch throttle levers from the autothrottle. The lamp is lit - lever declutched. When two thrust levers are declutched AT speed hold will be disengaged. In the model, the thrust lever control of the declutched levers is returned to the joystick axis, so preselect the right throttle position on the joy before declutching

380, 381 - B-52 panel of the NVU nav computer

382 - V-140 panel of the NVU nav computer

383 - V-51 panel of the NVU nav computer

384 - V-57 panel of the NVU nav computer (wind drift info). Will be preset from the Doppler system or, when the NVU operates from the SVS can be used to manually enter drift

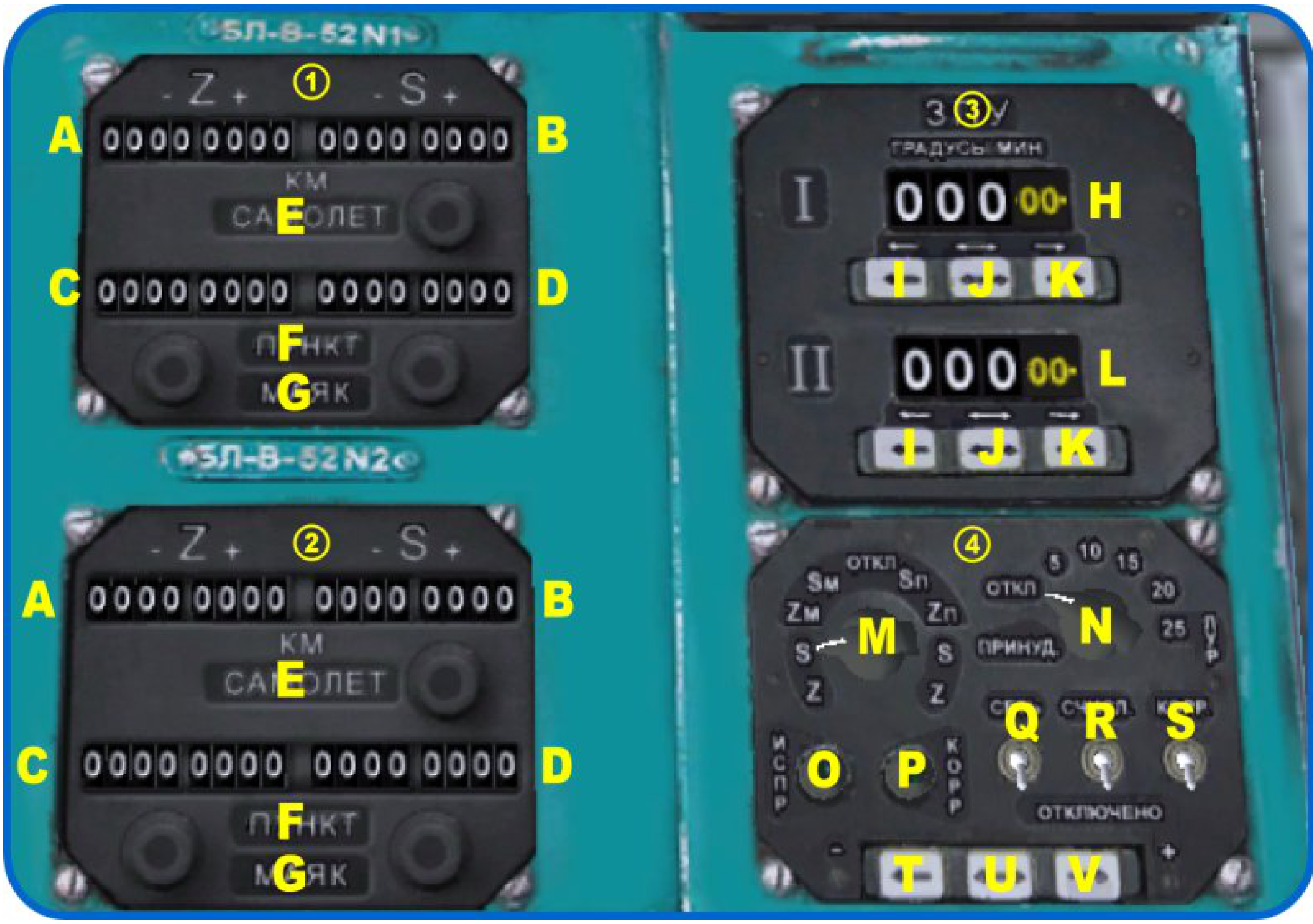

Fig. 8. NVU panels.

A, C - Cross-track deviation from the track(Z)

B, D - Distance to waypoint (S) at the end of the leg entered into the unit, negative is "not reached yet" (input usually done with negative numbers)

E - Placard "airplane" Indicates that this block currently holds the active leg

F - The placard "point" Indicates that this block currently has the leg distances entered in the lower indexes

G - Placard "beacon" Indicates that this block currently has the distances from the waypoint to the beacon entered in the lower indexes

H - Course for the first NVU leg

I - decrease course (-) of this leg

J - Toggle I and K between coarse and fine entry

K - increase course (+) of this leg

L - Course for for the second NVU leg, same controls as H

M - select the destination for distance entries

N - LUR (turn anticipation distance). "Откл" disengages leg switching and "принуд" forces the next leg to activate

O - Lamp "NVU ready"

P - Lamp "NVU updating"

Q - NVU power switch

R - NVU computation switch (engaged on takeoff)

S - Correction switch (when turned on, the NVU will update from the preselected RSBN beacon)

T - Distance decrease button (-)

U - Change T and V button step distance coarse/fine

V - Distance increase button (+)

On a real plane, the smallest NVU digit is exactly a kilometer, thus the maximum possible leg is 9999 km. In this model, you can switch the display to the scale of hundreds of meters. While doing so, all the parameters of the NVU stay the same, only the display changes scale to be more precise. To change the scale there is a hotspot on the B-51 panel (383), on the upper left screw.

Flight engineer panel

Fig. 9. Flight engineer panel.

501 - AC frequency Hz

502 - AC Voltmeter

503 - AC ammeter

504 - Voltmeter for the 27V DC bus

505-507 - ammeter DC buses (left and right)

508 - APU RPM in percent

509-511 - Throttle lever position indicators (angle of detent)

512-514 - Turbine RPM indicators, N1 and N2

515-517 - Engine EGT temperature, in degrees C

518-519 - Fuel and oil pressure/oil temp combined gages

521-523 - Fuel flow meters

524 - Airspeed indicator

525 - Altimeter

526 - Vertical velocity indicator

527 - Tanks 2 fuel level

528 - Tanks 3 fuel level

529 - Ballast tank 4 fuel level

530 - Total fuel flow

531 - Tank 1 fuel level and fuel totalizer (the needle of the totalizer has C on it for "СУММА")

532-534 - Hydraulic pressure in systems 1, 2 and 3

535 - Hydraulic pressure of the emergency brake system

536, 537 - Hydraulic fuel level (press the buttons underneath to display level)

538 - ACHS-2 clock. Additional scales and timer are not implemented

539 - Outside air temperature

540-542 - RA-56 hydraulic actuator switches in yaw

543-545 - RA-56 hydraulic actuator switches in bank

546-548 - RA-56 hydraulic actuator switches in pitch

549 - Hydraulic actuator crossfeed, not implemented on the model

550 - Stability augmentation in pitch switch

551 - Avionics power lights. If the lamps are on the respective 27V DC bus is offline and the avionics are not powered

552 - tri-pos switch for the AC power source - APU-GPU-none. "РАП" is GPU and is always available on the model.

553,554, 555, 556, 564 - AC and DC indicator source (generators, bus from the APU/GPU, batteries)

557 - Emergency inverter. Not used on the model

558-560 - Generator failure lamps. The lamp is illuminated when the generator is offline

561-563 - Generator switches

565, 567 - AC\DC inverters.

566 - Standby inverter lamp. Not implemented in the model

568 - Lamp "DC Bus on battery"

569 - Battery master

570 - APU master switch

571 - "Dry-run/Start" APU switch

572 - APU fuel pump switch

573 - Air bleed valve from the APU

574 - Start APU push-button

575 - Stop APU push-button

576 - Warning test APU panel

577 - APU warnings

Fig. 10. APU panel.

A - Oil level indicator. Not implemented

B - Oil pressure low

C - Temperature limit reached. Not implemented

D - RPM limit reached. Not implemented

E - APU failure. Not implemented

F - APU inlet open

G - Fuel pressure Ok

I - APU running and available

J - APU startup in progress

579 - Engine warning lights

Fig. 11. Engine warning lights

A - Oil low. Not used

B - Excess oil. Not used

C - Fuel pressure low

D - EGT too high. Not implemented

E - Bearing temp too high. Not implemented

F - Bypass valves. Illuminates when engine is on idle

G - Reverser bucket locks unlatched

H - Metal residue in oil. Not implemented

I - Oil pressure low

J - Fuel filter clogged. Not implemented

K - Halted due to EGT and TGT temperature. Not implemented

L - Dangerous vibration level. Not implemented

M - RNA covered. Lights at low RPMs

N - Reverser buckets out and engaged

O - Autothrottle clutched

P - "Release the throttles" command. Illuminates when the thrust lever is held and the AT is engaged on this engine. Not implemented

580 - Fuel pumps in tank 2 left

581 - Fuel pumps in tank 2 right

582 - Balancing light tank 2 left

583 - Balancing light 2 right

584, 588, 592 - Fuel pump lamps in tank 3 left

585, 589 - Fuel pump lamps tank 2 left

586, 590 - Fuel pump lamps tank 2 right

587,591, 595 - Fuel pump lamps tank 3 right

593 - Balancing light tank 3 left

594 - Balancing light tank 3 right

596, 597 - Light "transfer 3->2"

598, 599 - Light "transfer 4->2"

5001 - Auto tank selector indication light - "consuming from tanks 2"

5002 - Auto tank selector indication light - "consuming from tanks 3"

5003 - Auto tank selector indication light - - "consuming from tank 4"

5004 - Fuel auto transfer failure light

5005 - Transfer valve 3 -> 2 switch

5006 - Transfer valve 4 -> 2 switch

5007 - Fuel pump in tank 3 left switch

5008 - Fuel pump in tank 3 right switch

5009 - Fuel pump in tank 4 switch

5010 - Fuel pump in tank 4 (ballast)

5011 - Fuel pump lamps in tank 1 (engine feed pumps)

5012 - Fuel pump switches in tank 1

5013 - "Fuel shutoff valves open" lights

5014 - Fuel shutoff valve switches for engine 1, 2 and 3

5015 - Fuel meters power

5016 - Automatic balancing switch

5017 - Automatic balancing check light

5018 - Automatic fuel selector switch

5019 - Fuel source selector "auto/manual"

5020 - Flow meter

5021-5023 - Hydraulic systems 1, 2 and 3 low pressure warning lights

5024 - Emergency braking system low pressure warning light

5025 - Fluid level in the hydraulics tanks. Not implemented in the model

5026 - Pressurize the emergency braking system

5027 - 1 and 2 hydraulic systems crossfeed valve

5028, 5029 - Auxiliary hydraulic pumps for systems 2 and 3 (system 1 is cross-fed)

5030-5032 - EGT temperature meters switch

5033-5035 - EGT temp check

5036 - "Starter RPM too high" warning

5037 - Warning lights test

5038 - Engine start panel

Fig. 12. Engine start panel

A - Main starter switch

B - "dry run/start" switch. Dry run mode is implemented, but not very realistic, and with strange bugs. Perhaps in the future, this mode will be modeled more accurately. Now I do not recommend its use

C - Iginiter Heating switch, normally used when OAT is below -5C. Not implemented in the model

D - Engine tri-pos selector

E - Start button

F - Abort spoolup button

G - Lamp "PDA is working" Lights up when the starter is activated

H - Three button "windmill start in the air." Not implemented in the model

Avionics

Artifical horizons

The aircraft has two PKP attitude indicators (101). Each ADI receives roll and pitch data from it's own vertical gyro. This gets cross-checked with the third standby gyro. Bank verification system (BKK) provides reliable warnings in case the roll or pitch channel on the ADI fails, using flags on the instrument.

On the real plane, the roll/pitch signals are fed to the autopilot. In the model the autopilot operates off it's own gyros, this is done to simplify debugging

PKP is a combined device that indicates pitch and roll angles, deviation from the glideslope and desired AT speed. Also a two-needle flight director is provided, which is operated by the autopilot and also shows flags when no specificed nav source is available.

Attitude indicators use three svitches on the overhead 408, 409, 410 (left, right and standby). To init the gyros, press the two buttons on the autopilot panel (in the middle under a cover between the two yoke symbols). This will align the gyros, afterwards clear the BKK (bank control module) warnings using the "БКК тест" switch on the overhead (405)

In addition to the main PKP ADIs the plane is fitted with a standby artificial horizon (AGR), on the top of the captain's panel (115). It is completely independent and operates off the DC bus. Enable the standby ADI using the "АГР" switch on the overhead (404).

Altimeters and VVIs

On the captain's side:

UVO-15 metric altimeter (105). On the bottom there isa hotspot to enter the baro pressure (in mm Hg), displayed in the tape window underneath. 1013 hPa is 760 mmHg.

UVID-15 feet altimeter (117). The device is not connected to the SVS (static pressure system), and has its own hotspot to set the pressure (in inches Hg) and the pressure display window. Used to set a separate pressure since in the CIS you will get the pressure in QFE (so the altimeter reads 0 at the aurport) and QNH abroad. Must be switched on separately using the switch on the overhead (403)

VM-15 metric altimeter (118). Standby UVO-15, works from the SVS, has no pressure input.

Radio altimeter RV-5M (116). Has a hotspot to enter decision height, when at DH the yellow "H" lamp will illuminate and the "H" placard on top of the captain's annunciator panel will engage. Also an aural warning (long low-pitch beep) will sound. The instrument readout depends on roll and pitch of the aircraft. Enabled using switches 425, 426 (left and right). In this model, the copilot's radio altimeter is slaved to the captain's.

Metric VAR-30 VVI (104), meters per second.

Metric VAR-75 VVI (110). Designed to measure the velocity in case of emergency descent and has a coarser scale than the VAR-30

In this model, most of the copilot's indicators are slaved to the captain's, with the exception of the HSI. The copilot's HSI is is managed by a separate switch, and allows to control the VOR radial, as set out in the real flight manual.

Speed

IAS indicator US (108), is independent from the power supply. The device is equipped with a moving index, which shows the speed command for the autothrottle. If autothrottle is disengaged the index is slaved to the speed needle

KUS dual-mode speed indicator (113) shows the indicated and true airspeed, wide and thin arrows, respectively. In this model, I do not recompute the speeds using correction tables (as done on the real aircraft). Instead, I use the readily available

```
velocities/ve-kts
```

and

```
velocities/vt-fps
```

, respectively, taking into account the units of measurement. As I understand it, is what the KUS should be showing, but comments are always welcome...

Mach number indicator (109)

Air or ground speed USVP-K (320) is located on the right side of the central panel, close to the co-pilot. Depending on the selection made at the bottom of the instrument, the instrument shows the air speed of the SVS or ground speed, fed from the DISS Doppler system.

DISS

Doppler velocity and drift meter, DISS is designed to measure velocity relative to the ground, in two perpendicular planes. The DISS data is used by the NVU nav computer, the KUSH drift angle indicator and is also fed into the ABSU and STU autopilot systems to compensate for drift

DISS for Flightgear is modeled in a rather way, in particular: the accuracy does not deteriorate over water. DSS failure below 180 km/h is modeled and inhibited if the DISS circuit breakers have not been engaged

DISS uses three switches on the overhead - power, land/sea, NVU source switch (433, 434, 435, respectively). All three need to be engaged and in the up position.

Navigation radios

The aircraft is equipped with two sets of KURS-MP nav receivers. KURS-MP works with ILS and VOR systems, and in reality also with the somewhat antiquated SP systems (analogous to ILS). In this model, the receiver is also working with the DME, while the simulator allows different VOR and DME control, for greater realism.

ILS can only be handled by the left KURS-MP set, flying VOR - with both.

KURS-MP uses the switches 421 and 422. The choice of frequency and input radial is done with panels 445, 446. There are hotspots above and below digits. There are indicators "FROM" and "TO", signaling the beacon within range, even when the system is configured for ILS. This, once again, is a deviation from reality, but I thought this is negligible.

Information from the KURS-MP sets is delivered to:

- HSI indicators PNP in VOR and ILS modes;
- IKU Indicator (RMI), (106), if the switches at the bottom of the device are in the "VOR" position
- USHDB indicator (338), if the switches on the overhead stay in the VOR position. In this case, the opposite end of the arrow shows the Radial and the pointed end shows the bearing
- ABSU, autoflight with VOR or ILS

ADF Radios

The aircraft has two ADF sets, their panels are located on the overhead, 442 and 443. On each panel you can set the active and standby frequencies (there are clickspots to the left and right of the digits), the active frequency is selected using the two-pos switch on the top of the panel. The active frequency is highlighted with a green light.

The ADF receivers feed to:

- IKU Indicator (RMI), (106), if the switches at the bottom of the device are in the ARK position.
- USHDB Indicator (338), if the switches on the overhead stay in the ARK position. In this case, the arrow shows the bearing to the NDB

VHF comm radio power switch 429, 430.

RSBN

Control panel of the RSBN receiver, Pos. 438. The left knob sets the "tens" channel number, right - "ones". RSBN is enabled using the switch 437.

RSBN nav system feeds the PPDA-SH (321) and the DME displau (107) when the DME source switch is in the middle position. Also the NVU nav computer can update it's current position estimation from the RSBN that is being received. For more information, see the description of the NVU.

RSBN was a soviet system analogous to a TACAN with the same use cases (quick deployment in the field or on ships at sea, peer-to-peer aircraft detection and identification and using aircraft as signal repeaters for extra range). In the model, for RSBN to work we need to make the information about the RSBN beacons available to the base simulation, the beacon data is in the file

Navaids/nav.dat.gz

. RSBN support for FG is implemented similarly to the well-known MSFS scenery by Praydko & Gritsevsky. An RSBN station in FG is a VOR with a modified frequency setting. To install RSBN nav data on Unix:

1. Copy Navaids / nav.dat.gz into some backup dir, just in case.
2. Unzip Navaids / nav.dat.gz in it's directory.
3. Open the resulting nav.dat in your favorite text editor and remove at the end of the file the line "99."
4. Append rsbn.dat at the end of nav.dat, for example: cat rsbn.dat>> nav.dat
5. gzip nav.dat
6. Copy the edited file to the Navaids / nav.dat.gz. You'll likely need root permissions to owerwrite.

For windows the same applies, only need a gz-capable compression utility. You can combine the files in any text editor, because they are ordinary text files.

RSBN system only applies in the countries of ex-USSR, and abroad it can't be used. To be able to update the NVU in flights abroad, the RSBN receiver has been pimped to also receive VORs. To toggle RSBN into the VOR mode, engage the "Ident" RSBN switch on the overhead (424). In reality, this switch allows the ATC to see the flight blip on a smaller radar which is coupled to an RSBN station, but in the sim this is never going to happen - so we repurpose it.

In the VOR mode, the VOR frequency is preselected in the same panel with the same handles (438), but now the left knob sets megahertz, the right one - khz. To check the selected frequency, look at the tooltip at the bottom of the screen. From the standpoint of realism, the use of this mode is not recommended - a real navigator would plot VOR distances on the map and manually update the NVU throughout the flight.

ABSU

Automated on-board control system, ABSU - this autopilot of the TU-154. This is a fairly complicated set that always influences the aircraft, even when the plane is flown manually. The stability required for such an aircraft cannot be achieved cannot be obtained through aerodynamic design, so the ABSU is always helping the pilot smoothing his inputs a bit.

ABSU gets information about the spatial position of the aircraft from a variety of gyro sensors, acceleration sensors, radio and navigation systems. Not all of these sources are modeled in detail, but the most important functions and properties of the system are retained.

ABSU manages aircraft in yaw, bank and pitch in manual control, stab or armed (flight director) mode.

TU-154 has an irreversible hydraulic flight control system. Control efforts of yoke and pedals are transmitted through a system of rods to the front hydraulic swing (booster) and the output of the booster results in the movement of the control surface. Spring loaders are used to simulate air pressure effects on the controls.

ABSU output signals are fed to electrically driven hydraulic actuators (RA-56), which are mounted on the rod assembly. Thus, the autopilot is continuously connected in parallel to raw yoke and pedal inputs. In automatic mode, the control movements are mirrored in the cockpit. In manual control modes, ABSU loads the control spring loaders in parallel with the manual flight control inputs, providing the optimum control law.

RA-56 units have triple redundancy in each channel, protection from lockup and each of the units is powered by all three hydraulic systems.

ABSU is divided into the pitch channel and turn channel (bank and yaw). Each channel can operate completely independently of the other. One channel can be operated manually, the other - via the autopilot.

ABSU operates in the following modes:

- Manual control. In this mode the autopilot creates the desired control law, "assisting" the pilot.
- "Stab" mode, bank and pitch. Autopilot keeps a given pitch and bank angle, and is controlled using the the pitch wheel and the turn handle
- Automatic Mach or IAS hold on pitch. The aircraft will descend to maintain speed with low power and climb when excess power is available to maintain airspeed.
- Heading select ("ЗК" mode)
- Flying VOR radials("АЗ-I", "АЗ-II")
- Flying the tracks set by the NVU nav computer ("НВУ" mode)
- Intercepting and flying the localizer (mode "ЗАХОД")
- Intercepting and maintaining the glideslope (mode "ГЛИСС")
- Automatic go-around ("УХОД")
- Approach mode ("ЗАХОД" and "ГЛИСС" engaged together) enable autoflight on CAT-I ILS approaches, down to a preselected decision height (typically 60 m). Further descent and flare are done manually.

During approaches on final, autothrottle is available for speed control. It's forbidden to use the AT during other phases of flight.

The pitch channel and MET

In addition to the automatic modes, the ABSU pitch channel contributes to pitch inputs in manual mode. In all modes, the longitudinal channel ABSU has a pitch damper, providing the necessary stability augmentation.

Let's look at the workings of the pitch channel in manual mode in detail. For a comfortable flight, the aircraft must give the same pitch change rate response for the same yoke deflection throughout the whole flight envelope and the whole range of CG positions. The autopilot, affecting the traction control, adjusts the effectiveness of elevator movements and thus facilitates the flying. But where does the ABSU get the information about the adjustment necessary? To answer this question, you need to understand how the aircraft is trimmed.

Tu-154 has no separate trim tabs. Instead, it's got a special device called MET (trim effect device). MET is controlled by a rocker switch on the yoke just like a conventional electric trim would be, and moves the control column aft or forward, thus relieving the efforts of the column produced by the spring loaders (actually the spring loaders move and the control column deflects as a result). This in turn changes the loads on the ABSU and changes it's trim bias.

It is the information about the MET angle that is used for the required amount of correction for manual control. The pilot trims the aircraft in pitch using MET and the ABSU calculates the desired amount of correction based on the position of the yoke. Adjustment biases are chosen in such a way that in a wide range of operating speeds and CG the G induced per degree of yoke deflection stays the same.

Proper pitch stability augmentation works only when the aircraft is trimmed in pitch.

In automatic mode, the MET trim is disconnected from the buttons on the yoke and the autopilot drives the MET instead. This allows for continuous trim in automatic mode and makes the system more responsive. When the pitch channel is disconnected the aircraft remains trimmed. On this model, there will be no &quote;false trim&quote; alert though and the ABSU will revert the trim offset back to the stabilized position as soon as the trim rocker switch is released.

ABSU autopilot in pitch is engaged using the switch 367 on the center pedestal. The stability augmnentation in pitch is engaged using the switch 550 on the flight engineer's panel. Autopilot is engaged by pressing the green "СТАБ" button-lamp. (363), the button will illuminate and the pitch autopilot indication (358) will change to "СТАБ". On the captain's warning light panel the "стаб ПРОД" lamp will illuminate. ABSU will then maintain the pitch angle. Pitch can be changed using the pitch wheel (364).

Once pitch hold has been engaged, you can switch into Mach on pitch, V on pitch or altitude hold modes by pressing the lamp-buttons 359, 360, 361. When these are engaged the "стаб ПРОД" will go out on the captain's mode annunciators and the respective autopilot mode annunciators will illuminate ("стаб V"(141), "стаб M"(142), "стаб H"(140)). Operating the pitch wheel will disengage the V, M or H modes and put the autopilot back into pitch hold. When the switch 367 (Autopilot pitch) is disengaged, a gong sounds and the yoke symbol will appear on the "AP in pitch" annunciator. If the autopilot is off in bank the green "СТАБ" lamp will go off as well.

Bank channel

Roll and yaw controls are the bank channel of ABSU. Yaw damping is always on, and the main functionality revolves around the heading and nav control selectors on the top of the ABSU panel.

The stability augmentation in roll and yaw is not available, unlike the pitch channel.

ABSU in the bank channel can make coordinated turns, lead the plane along VOR radials or LOC signals or the signal from te NVU nav computer.

To engage the bank channel, enable the "КРЕН" switch (365), and click the button-lamp "СТАБ" (363). On the captain's mode annunciator panel the "стаб БОКОВ" (131), will illuminate, and the PN-5 nav program selector will reset to "СБРОС ПРОГРАМ" (347). &quote;СТА" will appear on the lateral channel mode annunciator (356). If roll was non-zero at the moment when the bank channel is engaged ABSU will automatically level out the wings.

In this mode you can control the plane using the "turn handle" (362), the turn will be coordinated, and the bank angle of the turn depends of the deflection of the turn handle.

After switching on the stabilization mode you can engage the "ЗК&quote; (heading select) mode by pressing the button (345). The heading selected on the left or the right HSI is used, depending on the position of the "ввод ЗАswitch" 322. The light &quote;ЗК" 130 on the captain's mode annunciator will illuminated.

While in bank stab mode, you can also select one of the navigation modes: АЗ-I (button-lamp 349), АЗ-II (button-lamp 350), НВУ (button-lamp 348). The first two will maintain VOR radials from the left or the right KURS-MP set respectively, the last one will fly the NVU tracks. To enable the nav modes, you must switch the KURS-MP receivers into VOR - to do so, engage the "ПОДГОТОВКА НАВИГАЦИИ" (351) switch and disable the "ПОДГОТОВКА ПОСАДКИ" switch. The radial you want to fly is set not on the HSI but to the left of the respective KURS-MP frequency on the overhead. When nav modes are activated, mode annunciators 132 or 133 light up on the captain's mode annunciator.

Examine the relevant section of the flight manual to understand how the ABSU flies VOR radials.

You can reset the autopilot into wing level mode anytime by pressing "СБРОС ПРОГРАМ" (347). ABSU will switch to "стаб БОКОВ" mode, button-lamps will go out, mode annunciator 131 will illuminate. To disconnect the autopilot in the bank channel, disengage the "КРЕН" switch (356). The bank channel state monitor 356 will show a yoke symbol and, if the pitch channel is not engaged too the green "СТАБ" button will go out. A gong alarm will sound to notify the pilot of the otto disconnect.

CAT-I approaches

ABSU provides two nav modes - enroute navigation and ILS approach. They cannot be engaged simultaneously - either switches 351 or 352 might be engaged, but not both. The enroute nav computer provides the АЗ-I, АЗ-II and НВУ modes, the approach computer - "ЗАХОД" and "ГЛИСС" modes.

Let's see how to fly a coupled approach using the ABSU.

- Navigation receiver Kurs-MP, the first set. The receiver should be set to the desired ILS frequency (445).
- The compass system TKS must be properly adjusted, and the HSI (PKP) white needle should be set the localizer heading (102-D) using the OBS handle on the right.
- The landing mode must be engaged on the ABSU panel (switch 352).
- ABSU should be in stab mode (switch 365 should be on, button 363 sould be lit)

Switch 354 engages the flight director needles on the ADI. In a coupled approach, the autopilot will follow the needles automatically, but when flying by hand they provide steering cues to the pilot. To fly an approach using the flight director (so called "director mode approach") use the same setup as above but do not engage the stab switches 365 and 367.

The aircraft can automatically intercept the localizer automatically when in other ABSU bank modes (STAB H, ZK or any navigation mode). When the autopilot is on, and the button "ЗАХОД" is engaged (353, 129 on the captain's mode annunciator), the autopilot will automatically intercept the localizer or hint the pilot on the movements required using the flight director. The intercept happens as follows:

If the aircraft has not yet entered the beam of the ILS, ABSU will steer the plane to approach the localizer at approximately 30 degree angle.

When the ILS beam is intercepted the ABSU will initiate a turn into the landing heading, nd the HSI needle will start aligning Afterwards the nav mode used to intercept the beam will be disengaged and the plane will fly the localizer.

If the aircraft has already crossed the localizer beam hen you engage "ЗАХОД" (353) the ABSU will make two coordinated turns to put you on the beam.

During the approach, the pitch channel may be either auto or manual. Once you are on the localizer you can engage the "ГЛИСС"(355) button to make the aircraft hold altitude until the glideslope is intercepted and then to fly the glideslope automatically. If you are in one of the autopilot pitch modes and the glideslope is intercepted "ГЛИСС" will activate by itself. When flying by hand and using the ABSU as a guidance, you will need to enagage "ГЛИСС" yourself. When glideslope mode is engaged the light "ГЛИСС" (137) will illuminate on the captain's mode annunciator panel.

During the flight on the glidepath, ABSU will use the radio altimeter output, just like on the real airplane.

ABSU does not have provisions for autoland. At decision height (usually 60 meters but no less than 30) the ABSU must be disconnected and manual flare must be performed by the pilot. In the model, otto disconnect is on the joystick fire trigger that has already been recommended above.

Speed on the glideslope can be taken from the tables in the POH, but for the convenience of a virtual pilot, in the model tips are given. Tip is called up by clicking on the hotspot on the stabilizer/elevator indicator PB (309). It should be remembered that the tooltip shows the values of velocities (Vr and Vref) for the current configuration of the aircraft, and after deploing flaps, for example, the Vref speed will change.

Autothrottle and GoAround mode

ABSU has an autothrottle subsystem. AT only works together with a coupled or director-guided landing, but known accidents have limited it's use to the coupled ILS approach only.

To engage AT, enable the AT mode switches 373 and 374. After booting for about seven seconds, two green lamps will illuminate to show that the AT is armed.

Engage the AT by pressing the green "C" button (372). The button will illuminate, "AT" (138) lights up on the mode annunciator. The AT will start to stabilize the air speed, which the aircraft had at the time of pressing the "C". Change the speed using the the rocker switch 375, the speed command will be displayed by the red bug on the captain's IAS indicator. The "fast-slow" bug on the ADI will also come up and show whether you are too fast or too slow. Rocker switch 375 also has a tooltip attached to it.

By default, the AT manages all three thrust levers. If necessary, one of the thrust levers can be declutched from the AT pressing the buttons 377, 378, 379. Once the lamp illuminates the handle is declutched from the AT and can be controlled manually. If more than one lever is declutched the AT will disengage.

AT system can be switched off by using switch 374, as well as the autopilot disconnect. After the AT is disengaged all thrust levers will assume the positions your joystick has at the moment, so prealign the thrust levers on the joy to not get sudden abrupt thrust level changes.

If the autopilot is flying the ILS and the throttles are advanced to max, automatic go-around will be initiated. The bank channel will go to wing level mode, and the pitch channel will adjust the pitch using the go around algorightm. In real life go-around can also be initiated using a button on the yoke, but on this model this feature is not implemented.

In the "go-around" pitch mopde the ABSU will change the pitch of the plane depending on speeds and flaps config. Go-around is disengaged just as any other ABSU pitch mode.

Navigation

TKS

Tu-154 uses the TKS-P2 course system for lateral orientation. The TKS consists of a few magnetic sensors and two gyros, and feeds gyroscopic and gyromagnetic heading information to various systems. The system has a dual GA-3 gyro unit, dual BGMK-2 magnetic course units, magnetic sensors, alignment controls and out-of-sync and failure warnings for all of these.

A special feature of the system is how the magnetic heading is devised. The gyro heading is used as a base and then adjusted using the BGMK modules, and then adjusted using the KM-5 adjustment modules.

The TKS model is quite accurate, except for the influence of acceleration on the gyroscopes and the errors associated with bank. You can assume that on the model the gyros are always stabilized. KM-5 adjustment modules are also not implemented yet. Generally, modeling gyro drift requires serious theory work, so this part has been postponed.

The power to the gyros is enabled using switches 411-415 on the overhead, and the TKS is adjusted using the PU-11 unit (436). Let's look at the gyro alignment procedure in detail.

When the power is on, gyro failure indicators (436-I, J) will go off. Further, when describing the PU-11 unit we will use the button codes shown in the respective screenshot.

First of all, the gyros need to be aligned to the latitude of the departure airport. Change the latitude in the scale A, by rotating the knob D ("с" is for N, "ю" is for S). Switch B is provided for automatic latitude entry, on the real TU-154 this switch would not be available and the navigator would have to adjust the latitude to the degree by hand (in practice this would have been done once at the departure airport and once before the descent).

Next, we need to align the GA-3 gyros - main and standby. Typically, gyros are first oriented to the magnetic course, but if necessary, on the real plane you could also massage their output using the KM-5 units to account for magnetic variation. KM-5 instruments are at the right of the copilot's seat (two round units). You can access them from the navigator workplace. In the center of the device, there is hotspot to enter the magnetic variation. In this model, during normal operation the KM-5 is not necessary.

The usual alignment procedure goes like this. The G switch goes to the up position, switch C to the left (MK), and you press and hold the "fast alignment" button H. At this point, the main GA-3 gyro will rotate and orient itself to the magnetic meridian, using signals from the mag sensor. While the button is pressed a tooltip will be displayed at the bottom of the screen where you can see the heading of GA-3 gyros and their BGMK adjusted output. In real life, to control the process of alignment, the navigator would be looking at the USH instrument (337), but in the model, unfortunately, this is not possible (you can if you build a multi-screen system)of course, if you build multi-screen system, you probably can).

When the main gyro will align to the required heading (it will be the heading of your airplane), you need to switch the "коррекция" (G) to the down position, to align the second gyro, and press the alignment button again. There will be a correction for reserve gyro. After the completion of correction, When the gyros have been aligned the two needles on the USH(337) instrument will align to the same heading (there is an inner needle for the main gyro and a bug outside for the standby gyro).

Now that the mag heading gyros are aligned, slave the gyros to them. Switch C goes to the middle position (GPK).

Now align the gyros to the magnetic heading (adjust the correlation between the gyro heading and magnetic heading in the BGMK). To do this, you need to press the fast align button once more and to keep it until the BGMK output stops changing, you should do this for both the standby and the main gyro (again using the G switch in the up and down position). In real life, you can see the effect of the correction on the IKU (RMI, 106).

The main gyro's BGMK output is fed to the captain's IKU, the standby gyro's - to the copilot's IKU.

Before takeoff, after the aircraft is properly aligned on the runway centerline, you can tweak the gyros with greater accuracy since you know the magnetic heading of the runway by the book. Pick the gyro you want to tweak using the G switch, and then reorient the gyros using the F rocker switch (right turns the gyro right and left turns the gyro left). The same operation is performed before flying the descent so that your gyros are aligned with the magnetic meridian of the destination airport (the difference accumulates when flying east or west and can be quite big - up to 60-70 degrees difference in heading).

In case the main gyro fails, consumers (HSI and NVU) can be put on the standby gyro using the switch E.

NVU

Navigational computing device, NVU was a principal nav tool on the Tu-154. The NVU accepts ground speed input from the DISS and great circle heading from TKS, and uses them to devise the tracks.

NVU system is rather cumbersome, and requires good route prep before flight. To use the system, you need some chart preparation. A good guide to the NVU ops is in the pnk_3.20.pdf document shipped with the ProTu model and the English version of it is included in pttu154_94eng.pdf, p.41, p.84. All that is mentioned for PT applies to the FG model except for the "virtual nav assistant" (not implemented here). Values computed by the NCalc app from the ProTu package should work properly with the NVU in Flightgear.

Systems

Stabilizer

TU-154 is equipped with a moving stabilizer. Stabilizer movement is used to adjust the configuration for landing and takeoff, and is **not** used for trim.

Stabilizer can operate in automatic or manual modes. In auto mode, the stabilizer is slaved to the deploying flaps, the amount of deflection depends on the position of the stabilizer control handle 302. Handle has three positions: "П-С-З" (nose-heavy, middle and aft-heavy CG). The required setting is selected depending on position of center of gravity (CG), % of MAC, according to the following guideline:

- up to 28% MAC - set to "П" (nose-heavy)
- 28% up to 35% - set to "C" (medium)
- more than 35% - set to "З" (aft-heavy)

In reality, the crew determines the CG using the loadsheet, and by elevator/stabilizer position gage (309) on final. When flying level at about 400 km IAS, the elevator needle should be within the thick green band. If it's lower, then your stabilizer is configured too for up, if it's above then the stabilizer is too far forward. Ideally the elevator needle should be between the yellow and the green bands.

In this model, CG position can be viewed by clicking the at the center of the gage 309. A tooltip will show the ref speeds and the CG position.

In automatic mode, flap extension will operate the stabilizer in sync - the more flap you extend, the more stabilizer deflection will result. The stab control can be overridden. To do so, open the lid 301, the automatic stab control will disengage. Use the toggle underneath the lid to move the stabilizer manually. The thick needle on the gage 309 will indicate the stabilizer deflection, and when the stabilizer servo is working the light 313 will illuminate.

Flaps, slats and spoilers

In this model, flaps and slats are simplified - in particular you have no separate slat control. Slats are always slaved to flaps.

Flaps are powered by the hydraulic systems 1 and 2 and they depend on the pressure available to these systems.

Flaps are controlled by the handle 451. In this model, handle 451 is controlled by the mouse, you can also use the standard sim commands for flap extend/retract. Assign a couple of joy buttons to these commands for convenience.

Flaps have 4 fixed positions: retracted, 15, 28 and 45 degrees. Landing flaps position - 45, in some cases - 28. Take-off should be performed with the flaps 28 or 15.

When flaps are moving, warning lights 314 and 315 will flash. Flap deflection can be tracked using the indicator 310.

Gear and Brakes

Landing gear, like the flaps, is driven by the hydraulics. In this model, gear extension depends on the pressure in system 1. Due to the lack of failures in the sim emergency operation from systems 2 and 3 is not implemented.

Gear handle 452 is used for gear control, you can use standard shortcuts (*g* and *Shift+g*). In reality, you would also have to set the gear handle to the "Off" position after operation but it's not implemented in the model - perhaps in the next release...

Gear extension is shown by the light board 311. When the gear is out and locked, three green lights will illuminate. When gear is moving three lamps show red, when the gear is in the lights go off. When flaps are extended but the landing gear is not an alarm will sound and the warning annunciatior "ВЫПУСТИ ШАССИ" will flash above the landing gear lights.

In this model, all the three struts are extended simultaneously. Extension failure of the front gear leg above 400 km IAS is also not implemented.

Steering of the front wheel uses the system 1, and is coupled to the rudder. You'll need to engage the steering actuator (447) and choose the turn angle limit (448): 10 degrees (takeoff and landing), or 63 degrees (taxi).

The model does not implement the free-castoring front wheel mode (when the actuator is disengaged), this has it's effects on crosswind landings. It is possible to calculate this using JSBSim, and perhaps this will be a priority for further development of the model. Free-castoring nosewheel is essential for correct simulation of crosswind landings.

Landing gear is modeled with a high level of detail. More than 30 animations are used to implement the complicated moves, along with some Nasal magic. Gear struts on this model give a good example of complex Nasal-assisted animations in FG.

The brakes are dependent on the pressure in the hydraulic system 1. As in reality, brakes will not operate if there is no pressure in the system. Perhaps the parking brake should be independent of the hydraulics - in fact there are no blocks under the wheels in flightgear :)

As in reality, the model supports differential braking. Assistive rotation of the front wheels on the main bogies is not modeled though.

Due to the lack of failures, the emergency brake is not engaged. In this version of the model, the brakes will neither fail, nor overheat.

Spoilers

The aircraft is equipped with outer, middle and inner spoiler sections. Inner sections are only used after touchdown and are slaved to the thrust reversers. Outer spoilers are used after touchdown and for assistive roll control together with ailerons. Middle spoilers are used after touchdown and can be extended manually to accelerate descent or to slow down the aircraft.

Spoilers make use of hydraulic system 1. To manage spoilers, use the handle on the center console to the left of the throttle levers, or the standerd spoiler axis in FG. In this model, the middle section can also be controlled using the keys *j* and *k*, inner - are extended automatically when the gear struts are compressed and thrust reversers are activated, like on the real airplane. Forced internal spoiler extension is not implemented.

Spoiler position for middle sections can be monitored on the handle on the center console. In addition, when you open the spoiler locks, light yellow placards 316 - 319 illuminate. According to the POH spoilers cannot be used on final.

Reverser

Engines 1 and 3 fit with thrust reversers. When the reversers are engaged, the special nozzle flaps deflect the jet stream forward-up and forward-down.

To simulate the reversers we used the ability of FDM JSBSim to deflect thrust vectors, which allows for relatively realistic reverse, separately for each engine.

In this model, thrust reversers can be operated by joystick throttle handle if the axis provides some idle detent. When you move the handle below idle the reverse bucket handles will engage. As the throttles are moved aft, engines go to full reverse power. Thrust reverser state is indicated by the lights 579 G, N on the flight engineer panel.

In the model, to use the reversers on joystick, you need to specify a response threshold. The threshold is defined by two variables: / fdm/jsbsim/fcs/revers-1-limit and /fdm/jsbsim/fcs/revers-2-limit. One sets the threshold for idle reverse, the second - for the full reverse. By default, the threshold is set to 0.1 (10% of the thrust lever travel) for idle reverse, 0.04 (4%) for full reverse. Change default values for your joystick in tu154-set.xml around line 378.

If your throttle axis does not have an idle detent, or you do not want to use the reverse, you can disable this behavior by setting

/fdm/jsbsim/fcs/revers-by-joy

to 0, by editing the line in the set-file. In this case, engage full reverse by pressing F2.

Electrics

Electrics are simplified. There is a bus, sources, consumers, works fairly well, and gives a simplistic view of the electrical system of the real aircraft. Since this version is not meant to be a true ops simulation, some details have been simplified. However, the potential that lies in the electrics code permits to model the whole system of time permits.

TU-154 uses:

- One 27V DC bus
- One 220V 400 Hz AC tri-phase bus
- One 36V 400 Hz AC bus

Power is provided by:

- Three generators, one per engine
- A generator driven by the APU
- Ground power (GPU) source

The system also uses two batterise, inverters and an emergency inverter

To power up the aircraft, you should:

Enable the battery master switch (569). Battery master should stay on throughout the flight.

Turn on inverters (565, 567)

Engage the GPU (switch 552 down position), if the aircraft is on the ground and the GPU is available. In this model, GPU is always available.

Once the APU is running, put the APU generator on bus (sw 552 up).

Once the engines are runnng, enable the generators (switches up 561-563, sw. 552 in middle position).

You can observe bus parameters using 501-503, 504-507 multiposition switches, as well as

553-556 and 564 multipos switches. In this version, these gages do not work very reliably.

Fuel system

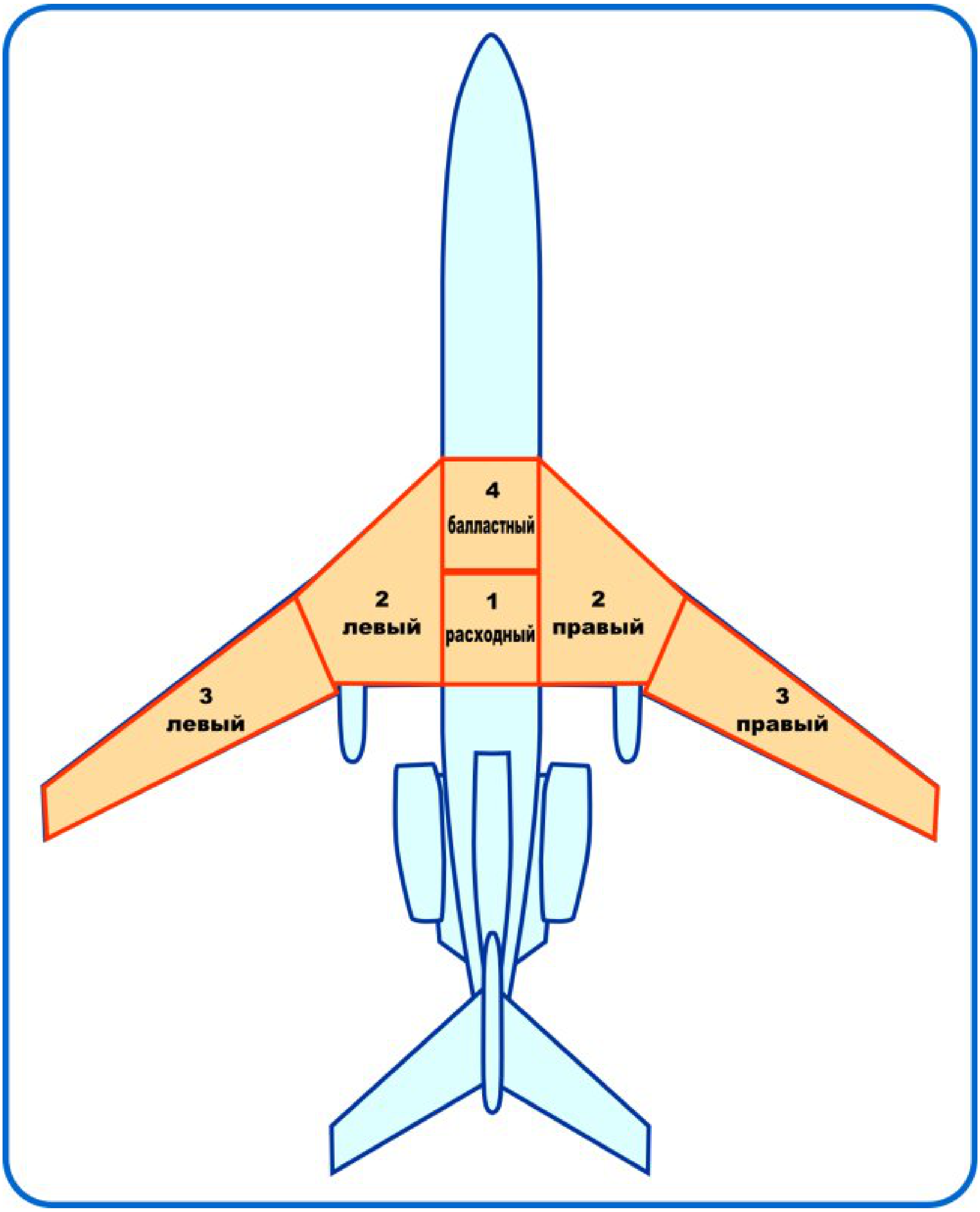

Fig. 13. Fuel tanks TU-154B.

In this model, the fuel system includes:

- Fuel tanks

- Electric pumps
- Valves, transfer pipes, cutoff valves, etc.
- Portioner
- Automatic Flow control system
- Automatic balancing system
- Fuel level meters, a totalizer and fuel flow meters

The fuel system of any airliner is a fairly complex. Tu-154 is no exception, and to properly manage the model you need to understand the basics of the system. The model implements the so-called "modified fuel system", which was built into the aircraft from the hull N 508 onwards.

Fuel is stored in six tanks: four tanks in the wings, and two - in fuselage. The main fuel is in the wing tanks, the tank 1 in fuselage is connected to the engines, and tank 4 - is used for balancing. Tanks contents:

Tanks 2 - 9500 kg per tank

Tanks 3 - 5425 kg per tank

Tank 4 - 6600 kg

Tank 1 - 3300 kg

Fuel pumps are installed in tanks 3 - 3 pumps, in tanks 2 - 2 pumps, in the tank 4 - 2 pumps, and in the consumable tank 1 - 6 pumps. Pumps in tanks 2,3,4 feed fuel to tank 1, from which four pumps feed fuel to engines. Also, from the first tank a separate DC pump is feeding the APU. For the case of generator failure a separate DC emergency pump is available to feed fuel.

The portioner pumps the fuel into tank 1 from tanks 2, 3 and 4 until tank 1 is full.

To ensure the correct sequence of fuel consumption, the system provides automatic flow control. The auto-balancer ensures the fuel in tanks is consumed in specific order to shift the CG forward as the flight progresses. When automatic fuel source selection is disengaged, it is possible to manage the transfer pumps manually using switches on the fuel system panel of the flight engineer.

For the case of fuel imbalance an automatic balancing system will crossfeed the tanks until the amount of fuel equalizes. When a pump in the tank gets switched off a lamp in the related tank area will turn yellow.

The system also has two manual switches for pumping fuel from tanks 3 to 2 and 4 to 2. This is done after landing to ensure the best CG for taxiing (make the nose heavier or lighter) or for the case when in the next flight the tank 4 will not be filled.

Fuel amount is displayed on the fuel level meters, one meter per tank group (each meter has 2 needles, one needle per tank). In addition, the system is equipped with flow meters that measure the instantaneous fuel flow of the engines (521-523). By integrating this information, an additional flow meter (530) continuously calculates the current balance of fuel. Before the flight, the device must be manually set the amount of fuel filled.

The procedure for starting up the fuel system:

- Turn on the fuel meters and flowmeter. Set the amount of fuel on the device 530, at the bottom of the device is a hotspot. The totalizer is on the device 531, the arrow "C"
- Turn the automatic flow control system (5018), and automatic balancing system (5016). Turn on the automatic mode of fuel consumption (5019). Lamp "automatic flow inop" (5004) should go out.

- Turn on the 4 pumps of tank 1 (5012). Green lamps will go on
- Open the fuel shutoff valves 5014, three green lamps 5013 will illuminate. Now the fuel can enter the engines, and the lights "Р топлива" on the engines panel will all go out (579-C).
- Turn the pumps of tank 4 (5009) and the pumps tanks 2 and 3 (580, 581, 5007, 5008). In automatic mode, these pumps are driven by automatic flow control, but you should keep them on in case that the automatic tank selection fails.

Depending on the amount of fuel the auto tank selector works like this:

- From tanks, 2 to consume to the balance of 3700 kg in each tank. Lights yellow lamp (5001) and the green lamp tanks pumps (585, 589, 586, 590).
- Of the tanks 2 and 3, to complete consume fuel from tank 2. Lit the lamp (5001, 5002) and the green lamp of tanks 3 pumps (584, 588, 592, 587, 591, 595) and 2 (585, 589, 586, 590).
- After tank 2 will empty, lamps 5001, 585, 589, 586, 590 are off. At this point in the tank 3 is about 1725 + -250 kg. Fuel consumed from tanks 3.
- In the case of uneven develop appropriate group of pumps will be switched off automatic alignment, and light yellow lamp (582, 583, 593, 594).
- After tank 3 will empty, lamps 5002, 584, 588, 592, 587, 591, 595 are off. Flow switch to the tank 4, light on lamps 5010 and 5003.
- After tank 4 will empty, lamps 5010 and 5003 are off, consumption will be made from the tank 1. After consume tank 1 to the balance of 2500 kg, light boards "Ostatok 2500" (Rest 2500 kG) and insert siren.

Engines and APU

There are three NK-8-2U engines on Tu-154B. It's a turbojet, 105 kN thrust takeoff. To start the engine and provide power to an aircraft there is APU TSA-6A.

In the simulation engine, focused on the reliability of high-altitude and high speed characteristics, and modes of behavior in the engine close to the tolerance. If the provision of performance came down to creative thinking about scheduling a "Practical aerodynamics" by Ligum, the fuel automatic had to simulate separately. As in the real engine of the model is applied full-traction method cutoff of fuel at takeoff mode at negative temperatures. But the jump in the draft closing bypass valves have not yet received.

APU - this additional engine, operating for the generator. In addition to providing electrical power from the APU selection of hot air to start the engine, and the aircraft climate control. In this model, APU - is another engine of another type of thrust close to zero. The simulator does not distinguish between the engine and APU, and therefore in-flight APU disabled tachometer shows non-zero rpm, as if his turbine was in the air stream.

In this model, the engine can be run only from APU. Starting in the air is possible, but not yet implemented. Also, no system failures, and the engine never fails, even if the virtual pilot not in compliance with restrictions on takeoff regime. Engine gauges show not a clear values, and if there will be willing to accurately simulate the temperature of the oil and bearings, vibration, and other "stop the T-gas" - welcome aboard!

To start the APU must be:

Turn on the power system of APU (570). Open APU door will be on (577-F).

"Run-cold" switch (571) - in the up position.

Insert the APU fuel pump (572). If the expense is the fuel tank, turn on the placard "P fuel" (577-G) and "Ready to Run"(577-H) will on.

Click "Start" (574). Green lamp automatic APU (577-J) start will on, on the tachometer (508) will increase speed.

After the APU stay to work mode, light board (577-I), and (577-J) off. APU is running, you can turn a generator on bus.

To turn off the APU, you need to click "Stop" (575), and after turbine shutdown - shut down the switches 570, 571, 572.

To start the engine you need:

Move throttle levers in the idle position.

Prepare the fuel system.

Start the APU.

Open air bleed valve of hot air from the APU. Translate into the top position toggle switch 573 and hold it until shut off board "ready to start"(577-H).

Include turbine exhaust termometers (515-517) switches 5030-5032. Thermometers to verify serviceability by clicking on the buttons 5033-5035.

Open the lid panel start engine 5038.

Set a toggle switch "Run-Off" to "Run" (577-A).

Set a toggle switch "Start - Cold" to "Start" (577-B). Cold start modeled, but not without glitches. In this version using the "cold start" is not recommended.

At temperatures below-5C, insert tumbler "heating ignition device (577-C). In this version of the engine will start at any position of the heating.

Select a engine by Choose a multiposition switch (577-D).

Open the cutoff cranes by moving the levers in the front position. Cutoff cranes are on the left side of the throttle levers, the left side of the flight engineer panel.

Click on "Run" (577-E). If all the preparatory operations are performed correctly, the green lamp lights up "PDA works" (577-G), will grow up (control of tachometer 512-514). When the engine go to idle rpm, may briefly light up the lamp "Dangerous turnovers starter" (5036).

If necessary, suspend the launch, click on "Ending Start (577-F).

After engine achieved idle rpm and "PDA works" (577-G) will off, then the switch (577-D) following the engine and repeat the starting procedure.

After all engines will running, put a switch (577-D) in the neutral position, turn off the tumblers "Run-off" (577-A) and heating ignition device (577-C). Tumbler "Running - Cold" (577-B) leave in the "Run". Close the door panel run.

After all engines achieved idle rpm, connect generators (561-563) to bus.

Hydraulic

Tu-154 has three completely independent hydraulic system. Hydrosystems supplied work (with a triple redundant) boosters - hydraulic powered units for elevator, rudder and ailerons, and actuators ABSU RA-56. In addition, further supplied:

From the first hydraulic works:

- Flaps, the first channel
- Gear, the main system
- Braking wheels, the main system and parking
- Spoilers, inner and outer sections
- Charging hydroaccumulator of emergency braking

From the second hydraulic works:

- Flaps, the second channel
- Gear, emergency systems
- Front wheel steering

From the third hydraulic works:

- Gear, emergency backup system

Each hydraulic system has a two-plunger pump, creating pressure. On engine 2, there are two hydraulic pump, on the left and right engines - one by one, and two additional pumping stations with electrical power from the AC.

The first hydraulic system uses:

- Pump left engine
- Pump center engine

The second hydraulic system:

- Pump center engine
- Pumping Station 1

The third hydraulic system:

- Pump right engine
- Pumping station 2

In each of the hydraulic system includes hydroaccumulator - balloon filled with nitrogen, acting as the storage of energy. In addition to the three hydroaccumulator within the system, there is an additional hydroaccumulator used only for emergency braking. Before the flight, emergency hydroaccumulator should be charging from hydrosystem 1.

You can connect the hydraulic system 1 and 2 through the electrically controlled valve. In normal operation, this feature is used to charge the hydraulic system 1 of the hydraulic pump 2, or before starting the engine for brake on, or after turn off the engine 2 after landing.

Hydrosystem themselves quite complex, and their interaction with customers at times recalls the puzzle. However, management of hydrosystems is quite simple. Governance:

Three switces under the cover 339 includes booster - hydraulic steering surfaces

Nine switches 540 - 548 include hydropower of aggregates of RA-56, three independent channels for each unit

Sw. 5028, 5029 include pumping stations 1 and 2

Sw. 5027 connect hydrosystem 1 to 2.

Button 5026 charges Hydroaccumulator emergency braking of the hydraulic system 1

Manometers 532-535, 125-128, lamps 5021-5024 and 121-124 are used to control the pressure

Indicator of level of fluid 536, 537, and buttons 5025 allow a rapid control the amount of fluid in the systems.

In this model, hydrosystems, except for the inclusion of boosters and RA-56 actuators, not required a crew maintenance. Pressure in the system appears after start of engines, and continues until the engines are running. As in the real plane, with the engine stops in the air pressure in the system creates a rotation of the compressor air flow. The degree of accuracy of modeling this situation is questionable.

Hydraulic model is quite complicated, and not even only because of the branched structure. Calculation of pressure in the hydrosystem, ie, computation of amount of energy stored in the gas spring of hydroaccumulator requires some mathematical support. All mathematics hydraulic cheat means JSBSim. Perhaps, on the theme of modeling the hydrosystem will write a separate article.

Examples

Starting engines

First, we have the power:

Turn the battery (sw. 569).

Turn the converter 565 and 567.

Turn the lights Bano (341).

Secondly, we need to start the APU:

Includes APU start (570) and start/cold (571). After a few seconds, turn on board 577-F ("APU door opened").

Turn the fuel pump sw. 572. Light board 577-G, H.

Turn automatic launcher by pressing the "START" (574). When the APU starts, turns placard "Out on the regime" (577-I).

Turn the APU generator on the network (switch 552 in the upper position).

And thirdly, we need to fuel pressure. Prepare to work the fuel system:

Turn fuel meter 5015 and 5020 flow meter. Exposes the fuel level on the device 530.

Turn automatic flow (5018), and automatic alignment (5016).

Toggle automatic flow in automatic mode (sw. 5019 in top position).

Turn pumps tanks 2,3,4 (sw. 580, 581, 5007, 5008, 5009).

Turn pumps expendable tank 1 (4-sw. 5012).

Turn cutoff valves 5014. I get a fuel pressure engines extinguished the placard "P fuel (579-P)

And fourthly, we need the hot air. Push the switch 573 in the upward position, and holds up until 577-H has gone.

Turn the temperature control of turbine exhaust (sw. 5030-5032).

Engines ready for launch. We translate the stop-cranes in the front position on the left side of the flight engineer desk, three-arm, with a red lamp failure.

Open the lid remote start engine 5038.

Turn launcher automatic (5038-A) and the "cold-launch" to upward ("launch") (5038-B).

On the real aircraft, in temperatures below -5 'C to include heating ignition device (5038-C). However, in this version of the model, the engine will run regardless of temperature and heating.

Start the engine:

Turn flashing lights OMI (342).

Choose 4-pos. switch (5038-D) engine for start.

Push button start 5038-E. If necessary preparatory procedures implemented correctly, the green lamp lights up "PDA works (5038-G) and the engine will gather rpms. After exiting the engine to idle rpm, quenched lamp 5038-G.

Choosing a switch (5038-D) following the engine and repeat the procedure.

If necessary, stop the process, you can start by clicking on 5038-F.

After starting the engines:

Set the 5038-D in the middle position and close the lid panel.

Connect generators to power bus (561-563) and put the switch 552 in the middle position.

By clicking 5026 charges hydroaccumulator emergency brake (control manometer 535) until the 5024 lamp gone.

Connects hydropower to RA-56 aggregates (540-548).

Turn the system improve the longitudinal controllability (549).

Turn off APU. To do this:

Close bleed air valve switch 573 by pressing down, until the fire board "is ready to run" (577-H).

Stops turbine APU by pressing the "STOP" (575).

Disable fuel pump APU (572) launcher and automation (570).

Preparing avionics

Preparation electric power:

Switch to view 4 (overhead).

Turn switches 401-420 to the upper position on the overhead, exclude sw. 405, 407.

Include both sets of Kurs-MP, 421, 422.

If you need RSBN - includes 423 and 424 if using RSBN in the VOR.

Turn switches 425-432.

Turn Diss, 433-435.

Turn placards in the passenger cabin 437. Passengers should keep in severity!

Preparation radio:

Set the frequency and course of ILS, or VOR radial (panels 445, 446).

Set frequency of ADF (panels 442, 443).

Set the COM-frequency radio (panels 440, 441).

Preparation work of gyro compass system TKS:

Press and hold "~" (tilde) to have a convenient overview of the panel PU-11 (436).

Set the current latitude by the handle 436-D, on a scale of 436-A. Or includes an automatic correction of latitude (436-B in the left position), if we do not care about reliability:)

Choosing the MK mode (switch 436-C in the left position).

Let's begin reserve gyro unit alignment. We put 436-G in the down position.

Press and hold the 436-H. At the bottom of screen, you can see a tips.

Hold down the correction, while the position of reserve gyro (GA-3-2) does not cease to evolve. When the fast adjusting of the reserve gyro is completed, an axis of reserve gyro will be displayed on the aircraft magnetic heading.

Proceed the main gyro. We put 436-G in the top position.

Again, press and hold the 436-H, until the cessation of rotation of the axis of main gyro. Controls are on the digital tip GA-3-1.

Axis of gyros on the magnetic course is not displayed perfectly, and between them will angle about a degree. This angle will be chosen later.

Turn off the regime of magnetic correction MK (switch 436-C in the middle of "GPK").

Let's set up blocks gyromagnetic course BGMK. To do so, press and hold fast to align 436-H prior to the termination of the magnetic changes in the course BGMK-2-1. After correction, the rate should match the main course gyro GA-3-1

We put 436-G in the down position, and holding the magnetic course correction control BGMK-2-2. Press and hold 436-H termination changes the magnetic course BGMK-2-2.

After making corrections, all courses are in line tips should coincide with the magnetic heading of aircraft, with a difference of no more than a degree.

Before take-off when the aircraft along the runway just presented, we need to manually adjust the axis of gyros GA-3-1 and GA-3-2 by 436-F switch, as accurately as possible based on the magnetic heading runway. The choice of the unit is made tumblers 436-G. Similarly, the axis of gyros will be transferred to the Meridian airport landing.

Continues preparation of avionics. Set attitude gyros MGV-SK:

Choose the view 1 (captain panel) and adjusts the review in such a way that you can see both the ADI (PKP) (101) and part of the IP-46 panel with a cap 357.

Open the lid 357, press and hold button below it. Seeing ADI turn to act.

Once ADI is aligned, close the lid 357.

Switch toggle switch 405 (on overhead) up and down, close the lid. This resets the bank signal error BKK.

Make sure that the signals are extinguished: "AG kontr" lamp, remove blankery AG with HSI (PNP) and ADI (PKP).

Turn on boosters. Open cover 339, turn on three switches, and close cover.

Turn on ABSU by sw. 407. You can see yoke symbols on 356, 658 indicators, and hear sound signal. If there are label “OTKL” on 356, 358, you should check missed operation. ABSU will fail if:

- Absent electrical power;
- Absent pressure in hydrosystems;
- Busters not engaged (339):
- Absent RA-56 hydropower (540-548);
- Longitudal control off (550)
- MGV failure or BKK error not cleared.

After check missed operation, you shoul re-start ABSU by tourn OFF and ON sw. 407. Take-off with ABSU failure is strongly forbidden!

Set the pressure in the SVS, by operate hotspot by altimeter 105 set to zero, and put pressure in futomer UVID-15 (117).

Avionics is prepared, except for the NVU.

Flying pattern

Start the engine and prepare avionics, as described above.

Turn boosters, closing the lid 339 if you don't do it early.

Turn the wheel steering (447), set the streering limit switch (448) to 63 deg (bottom).

Call a hint by clicking on the device 309, and determine the required position of stabilizer, depending on CoG % MAC position. When CoG least 28% selected "P", from 28% to 35% - the "C", more than 35% - the "Z".

Let's taxi. In the process of taxiing extract flaps in position 28, by the joystick or lever controlling 451. Stabilizer automatically take an right position, navigator report.

We put the plane precisely along the runway, and adjusts position of gyros of TKS on the PU-11 panel, switches 436-F, G.

Adjusts to the handle (102-D) the desired course of landing, if you plan to approach. White Arrow (102-F) to indicate a zero on the scale of the demolition of the figures in the PNP (102-C) coincide with the magnetic heading runway.

Turn calculator landing (352) and fly directors (354).

Adjusts handle (102-B) to crosswing course , usually under 90 degrees to the takeoff heading, based on the rolling yellow index of 102-L.

We put the steering switch (448) to 10 deg (up).

If we have done everything correctly, flashing off the placard "not ready for take-off" (155), and the crew will report on the readiness for take-off.

Set throttle to takeoff mode (or nominal if the take-off by nominal trust). Releases the brake (shift + B). Let's go!

During the run, control the speed and listen to the navigator. When the speed reaches Vr, raise the front wheel and taking off.

Retract landing gear after the climb 5-10 m.

We continue to climb and acceleration, so that to a height of 120 m speed was 320-330 km / h. At an altitude of 120 m starting to retract flaps. In the process of retracting, changing the angle of pitch, accelerates the speed so that by the end of a cleaning speed of about 400 km / h .

Increase air speed to 500 km/h.

At a height of not less than 450 m set thrust to nominal.

Turn autopilot - tumblers 365, 367, and button-lamp 363. Then the machine operates ABSU. In model, you can press key "D" for activate autopilot.

Upon reaching the desired altitude (about 600-700 m in normal condition), push-button light "H" (361). The longitudinal channel is beginning to stabilize altitude.

We fly our pattern. Push button-lamp "ZK" (348). The plane starts to turn on the course set by the left handle HSI, the yellow index. It is anticipated that the desired heading was set during the preparation procedure.

Managing yellow index "ZK", turn aircraft to downwing leg, controlling the position of the aircraft by radio navigation equippment.

During the downwing leg, reduces the speed so that the beam DPRM to have the speed of 400 km / h.

Set frequency of ILS to nav radio Kurs-MP, turn on ABSU landing calculator (352) and fly directors (354).

If the planned landing using autothrottle includes tumblers 373, 374.

Turn to base leg performing with a roll of 15-20 degrees at a speed of 360-370 km / h.

During the flight of base leg, deploy gear and produce flaps to 28, while braking at a speed not exceeding 360 km / h at the end of the release. Reduce speed to 280-300 km / h.

Turn autothrottle (button 372) and set the desired speed of wheel 375.

Turn to final perform by heading wheel or left handle of HSI (ZK).

After the turn to final leg, at a speed of no more than 300km / h extract flaps to 45. Reduce speed to the value of Vref, and at this speed to fly up to the entrance to the glidepath.

At the moment of crossing the glidepath, if the automatic approach is engaged, and aircraft has landing configuration, will include automatic glidepath mode GLISS. If the mode is not engaged automatically, it can force the push of a button - lamp 355.

If you fly manually \ by director, the plane balanced by using MET trimmer. For descent on glidepath, the deviations of vertical velocity from the estimated correct elevator, the speed deviation - only the rengine thrust. As the regime, the speed of the aircraft in landing configuration quickly drops, so throttle should move cautiously, with a step of no more than 5%.

Automatic mode of approach is necessary to disable the VPR (60 meters at standard conditions). Further descent and landing is manually.

Fly front of runway performed at an altitude of about 15 m.

Span end and fly to a height of 5 meters to continue to produce glidepath. At a height of 5 meters set throttle to idle and begin flare. By the end of flare make landing, the speed will be at 5-10 km / h less than the speed of crossing the front of runway. After landing engage reverse (slats will deploy automatically), gently lower the front landing gear leg and begin braking. At the speed of 140 km / h in normal conditions, reverse off. Apply braking.

We put the switch to turn (448) to 63 (bottom) before taxiing to parking. In the process of taxiing, retract flaps.

Flight with use of NVU navigational computer

To use navigational computer effectively, check proper Project Tupolev manual pages. Russian variant is Docs/PT_Docs/pnk_3.20.pdf, sect. 4, pg. 19-23, English is Docs/PT_Docs/pttu154_94eng.pdf, sect.7.3, pg. 84-91. In FlightGear version of Tu computer works same way as in original Project Tupolev version. You may use they's navigational calculators too.

Correct navigational complex work is available only from 99 SVN version, by May 2011, or 1.1 release. On time of that documentation writing release is not released yet.

It's needed to add beacons data for make corrections with use of near navigation radio system. Check near navigation radio system pages of that manual.

We will not discuss theoretical principles of navigational computing here. Only analyze some flight example with use of that, and own calculator realization, so as virtual navigator mate.

By request of our Polish friends we'll check out Warsaw-Berlin route, EPWA-EDDT.

Use http://fgfs.i-net.hu/modules/fgplanner/ planner to get result:

- EPWA
- MRA/Mragowo VOR-DME
- F/Pruszcz Gdanski NDB
- DAR/Darlowo VOR-DME
- HC/Heringsdorf NDB
- EDDT

Planner also give frequencies and geographical coordinates of beacons. As you may see, results have "deg.deg_part" format, same to inner FlightGear, not like Jeppesen or standart schemes that ordinary have "deg.min" value form.

In addition to flight plan we need Berlin variation, because VOR beacons installs on lines of magnetic meridians. In case no Berlin schemes presented You can get data from nav.dat file. Check, it's must have (+2) value.

Let's start preflight checklist. Start simulator in EPWA. Open tu-154B-2\Route Manager menu. That's normal simulator manager, we use it as navigational base interface. Add route by points, from takeoff point. If we add point data right, it's appear in list. Add names that planner gives before slash, MRA for MRA/Mragowo VOR-DME for example. By the way, You can add intersections here. It's not obligatory to make some straight route from beacon to beacon, navigational computer allow free routes.

After add of all points You can close route manager window, and open NVU Calculator window by same menu. On first run window will be empty. Press Calculate to look on calculated route data. On that phase it's needed to check that waypoints added correctly and way length approximate to expected.

In main calculator window will be enumerated great circles of route. For each circle initial and final points will be indicated, route length in km, course sets of takeoff and landing airports. Length will be negative, as common in NVU coordinates system.

Now add variations. For last point value 2.0 in “Destination mag var” must be added, for initial point set “Use current” tick. Press Calculate again and check that angles in main window ganged, and bracked values too.

Now choose correction point and add correction data. For that route last part, № 5, may be corrected, on Tempelhof beacon with 52.4731N, 13.405389W. Add this data in lower calculator string. Add great circle number in “Beacon for route” field, latitude in "lat", longitude in "lon". Do not add “deg.min” tick, because data in “deg.part_of_deg” format. If You are use beacon data from schemes, set tick and use "deg.min_part_of_min" form, without dot of some else separator.

Now press "Add", and, once again, “Calculate”. As You may see, beacon data appears in window, in final route part. If all done well, and nothing confused, as wrong sign that could move beacon in other hemisphere, we'll get Sm and Zm that give us vector from last waypoint to beacon, from EDDT до Tempelhof in our case.

Ok, all data collected now. We can start engines and process standart checklist. After startup and systems preparation, switch on navigational computer, 383-Q on Fig. 8. Green lamp must lighted. If not then check doppler's angle and leeway gauge (DISS) and aerial signals system.

Open navigational calculator again. Set “Virtual navigator” tick and pres “Calculate”, by that we activate virtual navigator who'll download current data portions in computer on approach to next route points. If You are wish to do all the work manually, You can leave virtual navigator in offline mode.

Data for download in NVU presented in calculator window. S downloaded in "Plane" or "Point", ZPUdep, or after change TKS compass system - ZPUdest, in proper given way angle console, correction data in "Beacon" an "Map angle".

Little interlude. We can download data in NVU in complete manual mode, by use of proper consoles. In real life real navigator do that. In model some semiautomatic download mode available. Simple click by mouse on selected route in calculator window. If some calculations produced right now, and we are already fly by active half kit of NVU, then selected data downloads in inactive half kit, "Point" counters, and selected route will be active after current route completion. If no calculations processed then data will be downloaded in active half kit, "Plane" and next route part data will be downloaded in inactive, "Point", by calculator window route points progression.

thereby, we can download data in NVU from any selected route, on Earth and in air, skip routes on need, and so on.

When we are use virtual navigator, it's needed process that procedure of NVU data download before flight, to let navigator knew which route data must be downloaded. Check that "Numeration", 383-R is off, click on first route and see how current and next routes data downloads in "Plane", "Point", and "Given way angle" counters.

Now return to our flight. Taxi to runaway, takeoff. On takeoff switch on "Numeration". NVU begin to count distance after reach of 180km\h speed. After takeoff and out to echelon scheme completion we'll get nonzero values on "Plane counters". On climb we can head craft to route line manually, or left that to autopilot navigational computer.

To do so: switch on "Kren" and "Stab" if it is not switched on already. Switch on "Navigational prepare" tumbler and press button lamp "NVU" on pn-5. Green board "Navigational computer" will light on indicators panel, white needle will work off downloaded active route way angle on navigational routine indicator, position plank will bend to side and will show Z, craft will start turn and then finished it out to downloaded route angle.

After set on route craft will go on it. If You are turn virtual navigator on, then route parts data will be downloaded in navigational computer automatically. On 2km before next point navigator will notify "Approach to next route point", by voice. To let navigational computer half kit change, we must set turn anticipating by selector 383-N. Real anticipating depends on speed and bend sharpness, angle difference of route parts. Incorrect anticipating may lead to additional turn on route parts change.

If selector 383-N stays in "Off" position then route parts data change will be not processed, and virtual navigator will be switched off too. If You are set selector to last left position then change will be processed manually.

In process of flight we must set radio systems and control progress on many navigational information sources. Navigation must be integrated. Correction on last route part already planned. After set on that part, correction parameters must be downloaded in active half kit, in "Beacon" counters must be loaded beacon coordinates. If it not presented, as example, because of virtual navigator error, then it's needed to add it manually, by switching of 383-M selector in Sm, then Zm position, and setting coordinates data by 383 T-V buttons. U button multiply step of adding data on ten, map angle adds by 340 console.

In real life, navigational computer can be corrected only be RSBN, radio tech system or closer navigation beacons, that system was installed only on exUSSR territory. Moreover, in present time civil RSBN stations is out of operation and changed to VOR-DME stations. RSBN system, as it expected, will be used only in military purposes.

Original RSBN system use not frequencies, but fixed channels. Two verniers on 438 console let choose up to 40 of that. But in model there's possible to use VOR beacons to correction. To move RSBN to work with VOR beacons, it's needed to switch 424 tumbler. In that mode, left knob of 438 console set megahertz, right set kilohertz of frequency. Selected frequency is up in hint string. In real life RSBN receiver could not work with VOR signals, but that opportunity presented in model. Imagine that on Soviet forces departure one RSBN beacon was forgotten, and it continue to work, camouflaged as VOR-DME Tempelhof beacon. :)

It's needed to tune on selected beacon. Tempelhof beacon frequency is 114.1 Mhz. Switch on tumbler 423, and set 114.100 frequency by console knobs, guided by hint string. If we are tuned correctly, then azimuth and distance indicator 321 will revive. Indicator will show to us radial relative to true meridian, RSBN beacons oriented like that, and distance. To copy distance on commander indicator, set 120 selector in middle position.

If all correction data, Sm, Zm, correction angle, downloaded into navigational computer, craft is on correct great circle and RSBN is tuned then we are ready for correction.

Switch on "Correction" tumbler 383-S. If RSBN signal is presented then green light 383-P will light on. "Plane" active great circle counters, that was spin slowly, will spin faster, and after few seconds, slower again on common speed. It's possible that nonzero Z value will appear with that process, and, as result, craft will start bend and compensate correction error by that.

Switch off "Correction" tumbler. That's all, correction processed. Beacon signal enter the navigational computer, and accumulated reckoning error was eliminated. Craft complete bend an set on new right trajectory.

If some error was made on data enter process then, on most cases, reckoning process will be destroyed completely, and flight could not be proceed on navigational computer no more. I'll be needed to shift on another navigational means. And, yes, navigator error can cost much to passenger and crew in some times.

It's recommended to proceed correction after course system shift to landing airport course. It's important and complex flight part. And errors on course system shift stage can make troubles to crew. You can read about course system shift procedure in Project Tupolev documentation, but in possible to simplify procedure in our case. Before descent from flight level open navigational computer calculator and press “Apply fork” button. If needle on navigational routine indicator does not move to right position, it's happen on slow computers, then change active "Given way angle" by I-K buttons of 382 console, change angle on tick up, then on tick down, on place again. That's all course system moved on landing airport course, and, gyro course of course system will correspond with magnetic course on airport after descent.

Then craft move on final route part, it's needed to set linear bend anticipating selector to "Off" position to prevent great circle change in last route point. After "Plane" counters will count to zero Your route is over. Navigational computer had take You to final route point, approximately in the middle of EDDT runaway. You are not believe in that? Switch to outer view and, if You done all correctly, You'll make sure of that on Your own. :)

Limits

Max takeoff weight - 98 t.

Max landing weight - 78 t.

Max IAS

- below H=7 km - 600 km/h
- above H=10.3 km - 575 km/h

Max M above H>7 km below 10.3 km - 0.88

Flaps limits

- 15 - 420 km/h
- 28 - 360 km/h
- 45 - 300 km/h

Max IAS by gear deploy/retract - 400 km/h

Takeoff:

Vr - see help string

Climb:

- Engine thrust - nominal, 92% ITE.
- Climb IAS - 550-575 km/h H < 9.5 - 9.7 km
- Climb M - 0.8 - 0.85 H > 9.5 - 9.7 km

Landing:

Vref - see help string

Center of Gravity position

- Min CoG for takeoff - 21% MAC
- Min CoG for landing - 18% MAC
- Max CoG for takeoff, cruising and landing - 32-40% MAC