Mi-17 HELICOPTER
FULL-FLIGHT AND FULL-MISSION
CREW SIMULATOR

About Energy 2000

- ◉ LLC «Research and Production Company «Energy 2000» (Energy 2000), was founded in Kiev (Ukraine) in 1999. Company has 19 years experience of development, production, supply and maintenance of modern simulators and training systems for various purposes

- ◉ Having high qualified team of system architects, developers, analysts, engineers and subject-matter experts, Energy 2000 successfully develops Modeling & Simulation software with high level of quality

- ◉ Energy 2000 provides customers with cost effective, high-fidelity turn-key solutions

- ◉ More than 106 different military simulators have been successfully delivered to customers in various countries over the past years (Algeria, Azerbaijan, Congo, Ethiopia, Iraq, Kazakhstan, Myanmar, Sudan, Vietnam, Ukraine, USA, Chad, Nigeria)

Energy 2000 Products

- ◎ **Simulators for Land Forces**
- ◎ **Simulators for Air Forces**
- ◎ **Cockpit mockups**
- ◎ **Motion Systems**
- ◎ **Visualization Systems**
- ◎ **CGF (Computer Generated Forces)**
- ◎ **Geospatial Applications**
- ◎ **Integration of different simulators into Land and Air Forces training centers, as well as Combined Arms Training Centers**

Introduction

Get the full flight Mi-17B-5 helicopter crew simulator with the required characteristics

Use of Mi-17B-5 helicopter crew full-flight simulator in training process

Objectives

The way to suit the requirements

Mi-17B-5 helicopter crews

The objective is to obtain high level skills to accomplish flight missions under all conditions

Purpose

The Simulator (FFS) is designed to familiarize and train Mi-17 helicopter crews, including crew commander (left pilot), navigator pilot (right), and on-board engineer to perform full package of flight control, and navigating functional procedures, with use of on-board systems and equipment, as well as effectively communicate and cooperate, and execute emergency procedures in case of equipment's and on-board systems failure in accordance with Rotorcraft Flight Manual in order to shape and maintain steady skills in helicopter handling under different flight conditions.

General simulator's characteristics satisfy the requirements, specified for level 'D' full flight simulators (FFS) (according to CS-FSTD(H) «Certification Specifications for Helicopter Flight Simulation Training Devices») and ensure accomplishment of pilotage and navigation tasks in accordance with Rotorcraft Flight Manual.

Simulator's architecture ensures its timely modernization (subject to customer's requirements), as well as its integration with other simulators (within unified combat environment, in accordance with IEEE 1516.3 standard).

Simulator can be used within unit's combat training system, as well as in educational process of military institutions to perform Mi-17 piloting procedures under different flight conditions.
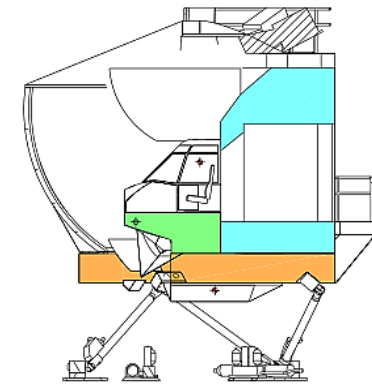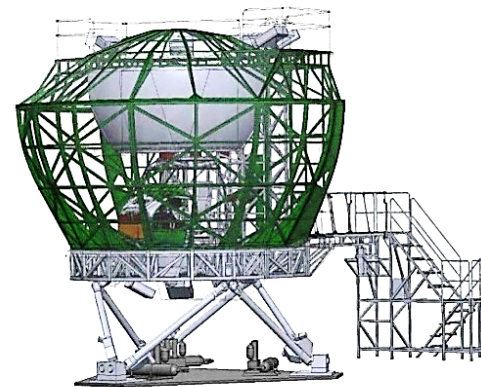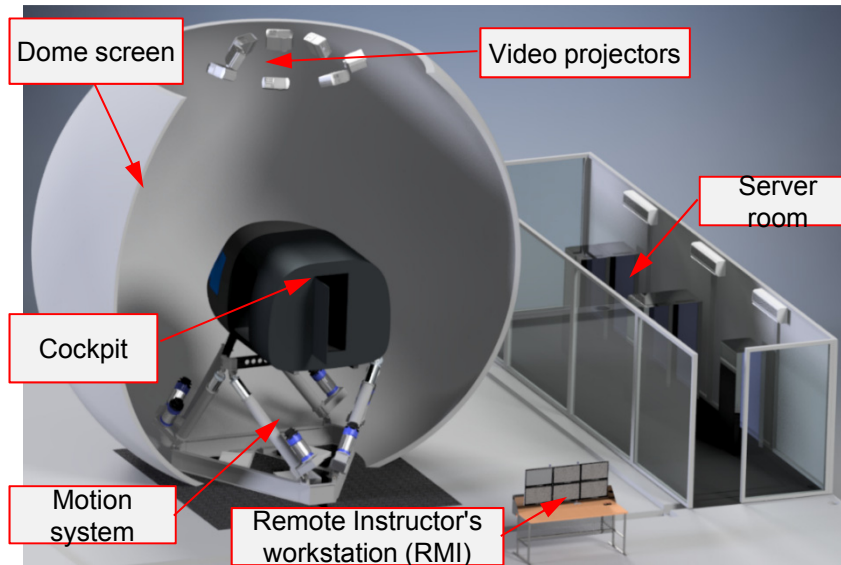
Simulator architecture

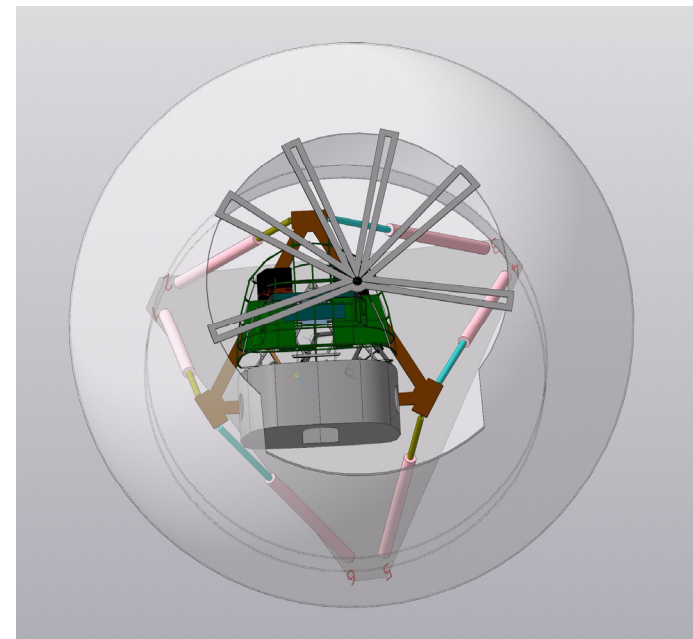The Cockpit mounted on the motion system and **static projection screen**

The Cockpit and static projection screen mounted on the motion system

- Dome screen
- Video projectors
- Server room
- Cockpit
- Motion system
- Remote Instructor's workstation (RMI)

VS

Mi-171 FULL FLIGHT SIMULATOR

Simulator architecture with provision for continuous yaw rotation (360º)

Mid-position

Main technical characteristics

- ◉ Dome screen diameter   – 10 m
- ◉ Dome screen height   – 8,125 m
- ◉ Vertical display size   – 110º(+55º/- 55º)
- ◉ Horizontal display size   – 360º
- ◉ Sphere base diameter   – 6,4 m
- ◉ Sphere upper edge diameter   – 4,784 m

Simulator with circular rotation (360º) projection system characteristics

№	Title			Value
1	Dome screen radius, m			5,0
2	Continuous vertical picture angular dimensions, degree			110
3	Continuous horizontal picture angular dimensions, degree			360
4	Screen illumination, foot-lambert		minimum	5,06
			maximum	18,57
5	Image resolution on the screen	arc min/OLP	maximum	2,49
			minimum	4,18
	pixel size on the screen	arc min	minimum	1,25
			maximum	2,09
6	Quantity of projectors	4k type		21
7	NVG support			+

Comparative figures of different simulator's architecture

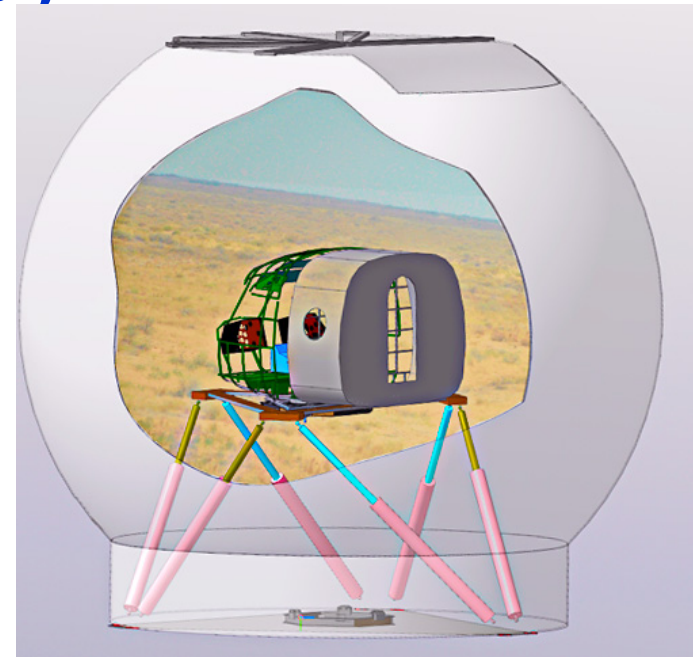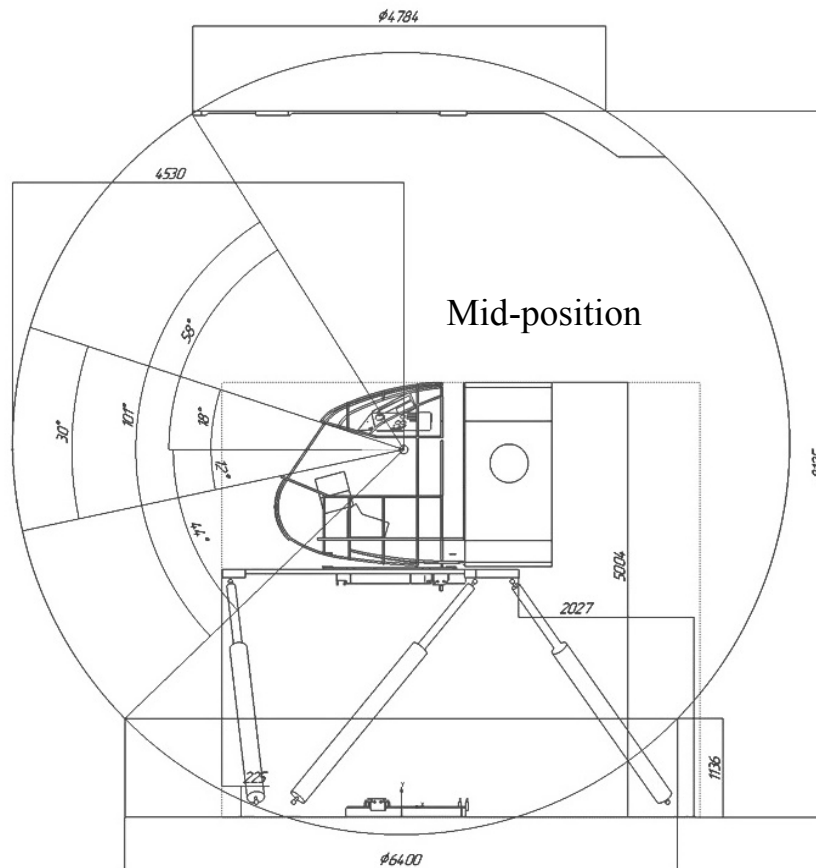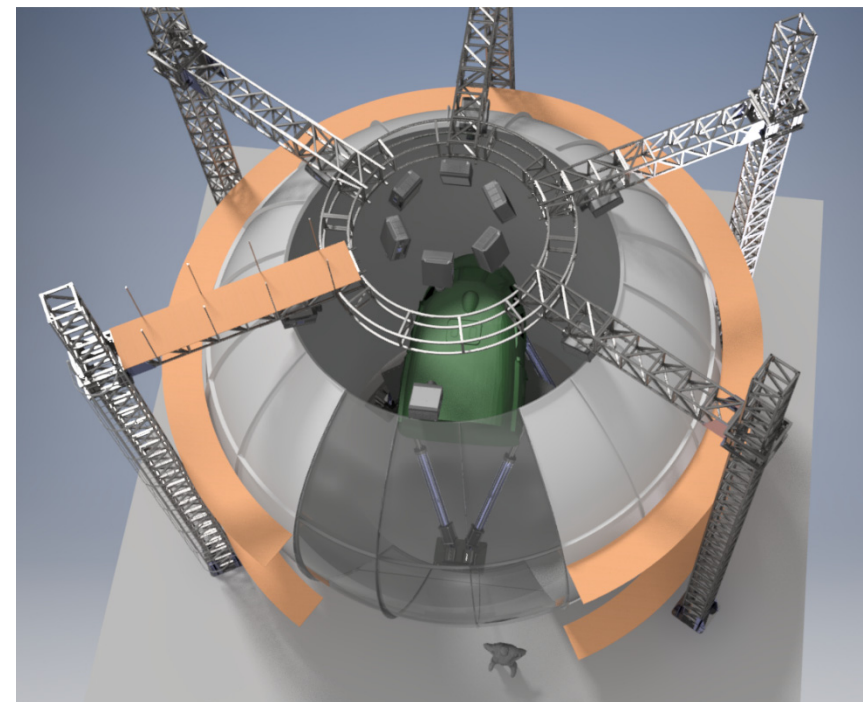| Features	Cockpit mounted on a motion system and static projection screen	Cockpit and static projection screen mounted on a motion system
Up gradation capabilities – continuous cockpit yaw rotation (360º)	**Capable**	**Very difficult** and **expensive** technical solutions
Projection screen angular dimensions ◘ vertical ◘ horizontal	110º 360º (possibly)	80º 240º
Motion system's payload limit, tons	9,0	14,0
Motion system's power consumption, kW	*12,0 -14,0*	*25,0 – 30,0*
Dome screen's radius, m	4,5 - 5,0	3,6
Training room's height, m	*10,0 - 12,0*	*12,0 – 16,0*
Protection of visual system's projectors from vibration	Not required	Mandatory
Motion system concrete base depth	0,7-0,9 m	>1,5 m
Helicopter flight evolutions simulation principles	Physical **similarity** - motion-based cockpit, maneuvering against static screen (static ambient environment)	Physically **approximate similarity** - motion-based cockpit fixed with the screen, maneuvering together as integral part
Serviceability and maintainability	*Medium* Only cockpit mockup, **traversing circular rotation rack** and vibration platform are mounted on the motion system top plate, which have good access for maintenance	*Low* Dou to location of cockpit mockup, vibration platform and **visual projection system** on the top plate of motion system

Simulator structure

COCKPIT SIMULATOR
- COCKPIT CONTROLS
- SIMULATORS OF DEVICES
- ACOUSTIC SYSTEM
- VIDEO SURVEILLANCE SYSTEM
- STATION FOR CREW CHIEF/ SCANNERS (IOS)

CAN- network data exchange

System for simulation of intercom and radio-communication

VISUAL SYSTEM
PROJECTION SCREEN COMPLEX
IMAGE GENERATORS

REMOTE INSTRUCTOR'S OPERATING STATION (RIOS)
Server RIOS

SOFTWARE AND COMPUTER COMPLEX
- MODELS ONBOARD SYSTEMS
- MODEL DYNAMICS FLIGHT
- MODEL EXTERNAL ENVIRONMENTS
- MODEL ACCUSTIC EFFECTS

Computing and control system
Server

Local area network (LAN)

MOTION SYSTEM
ACTUATORS
INTERFACE DEVICE
POSITION SENSORS
PLATFORM CONTROL MODULE
VIBRATION CONTROL MODULE

NETWORK HARDWARE
PRINTER
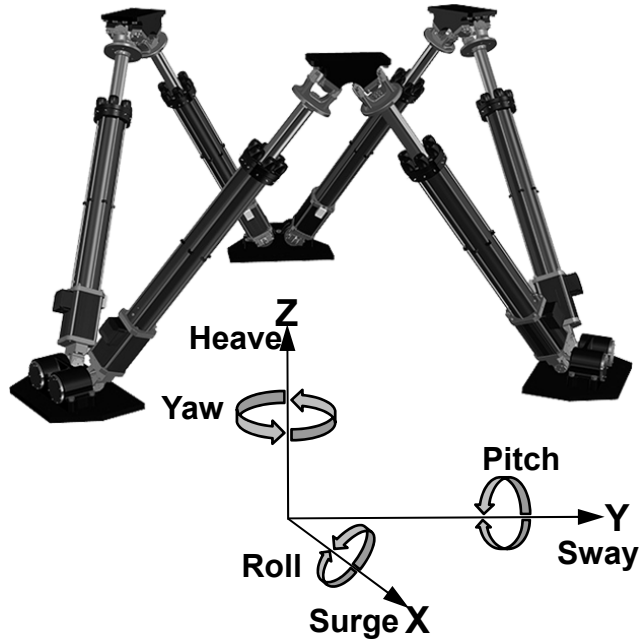FLIGHT DEBRIEFING SYSTEM

Database

Cockpit simulator

Helicopter cockpit simulator's internal dimensions, components, location of crew members seats, organic controls, equipment and accessories mockups are fully compatible with Mi-17B-5 helicopter cockpit (variant and series specified by customer), with specific additional equipment.

Motion system

Simulator's motion system intended to replicate roll, pitch and yaw characteristics of imitated helicopter, as well as surge, heave, sway and acceleration effects, which influence crew on the ground and during helicopter flight.

Simulator employs electromechanical 6DOF motion system, certified for level D FFS with payload:

◘ for cockpit simulator mounted on motion system with static projection screen - up to **9 000** kg

◘ for cockpit simulator with static projection screen mounted on motion system – up to **14 000** kg

Continuous (possibly 360º) yaw rotation is realized in simulator to rise adequacy of crew member's perception of on-course helicopter maneuvering.

№	Parameter's description	linear displacement, canting and rotation angles	linear and angular rate displacement	linear and angular acceleration
1	Surge displacement	±1,0 м	0,90 m/s	±6,8 m/s²
2	Sway displacement	±1,0 м	0,90 m/s	±6,8 m/s²
3	Heave motion	-0,67 +0,64 м	0,64 m/s	±9,2 m/s²
4	Roll	-28º +30º	26 º/s	±140 º/s²
5	Pitch	±28º	24 º/s	±140 º/s²
6	Yaw	±360º	26 º/s	±250 º/s²

Vibration system

3DOF vibration platform is used for replication of vibration forces influencing helicopter crew during a flight, with following characteristics:
- ◎ Controlled vibratory frequency 3-50 Hz
- ◎ Controlled vibration amplitude 0-0,5 mm
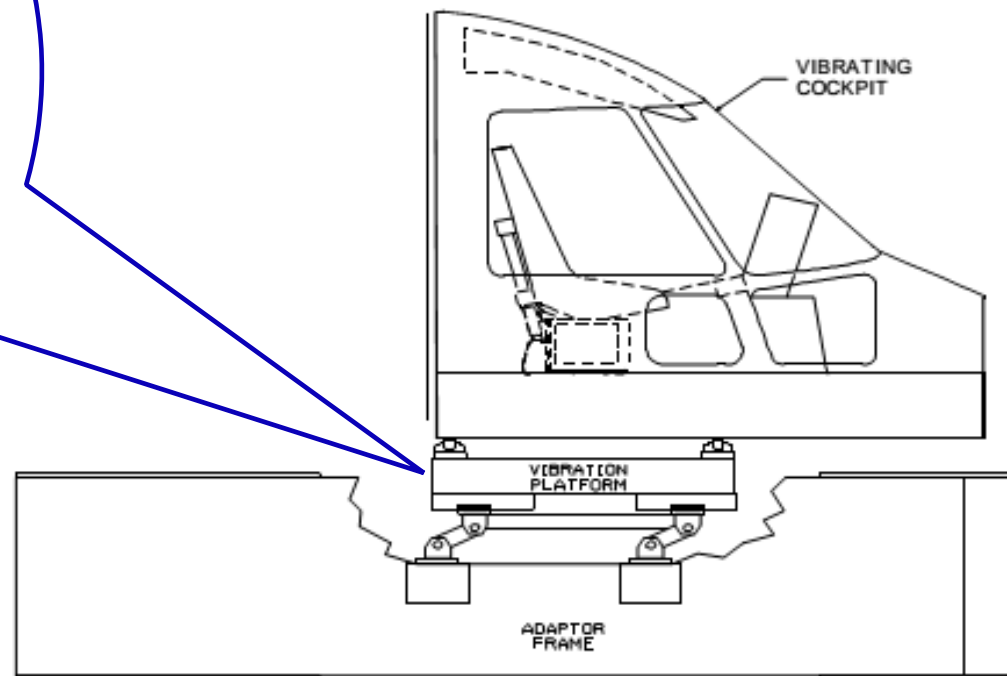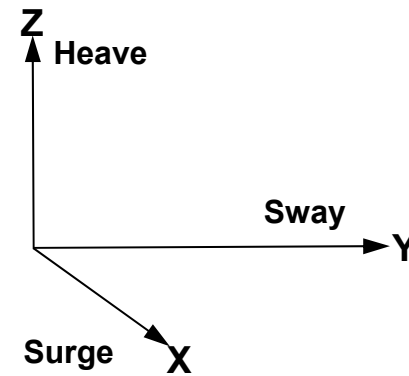
Visual system

Ambient environment projecting visual system is used in simulator to ensure flight and navigation capabilities during training in accordance with Visual Flight Rules, as well as to provide visual observation, surveillance and simulated firing capability with respect to meteorological conditions

Licensed visualization program **UNIGINE** is used in simulator providing:

Accurate atmospheric model

- ◎ atmospheric light dilution based on Relay's models with support of atmospheric physical parameters including density, altitude above the sea level, depolarization and pollution
- ◎ dynamic alternation of day and night
- ◎ imitation of earth curvature
- ◎ dynamic weather effects, such as rain, thunder and lightning, snow, wind influence on objects
- ◎ night sky with Moon and stars (based on star-field map)
- ◎ 3D volumetric clouds with shadows

Airdrome's lighting facilities

- ◎ special light sources (such as precision approach path indicators, touchdown zone lights, runway end identifier lights etc.)
- ◎ long approach visibility (from several kilometers)
- ◎ compatibility with multi-channel visualization
- ◎ visibility test depending on look-up angle
- ◎ pulsed approach and lead-in lights flashing
- ◎ light sources rotation with scheduled frequency

Detailed vegetation

- ◎ vast areas with detailed and realistic vegetation

Dome screen with multi-channel projection system

Visual system characteristics

Ambient environment modelling capabilities

◉ Reconstructed ambient environment images are fully compatible with imitated flight, meteorological, navigation conditions, terrain landscape, as well as corresponding helicopter systems indicated values: horizon indicator, radio altimeter, Global Positioning System (GPS)

◉ Decrease of brightness effects of non-self-luminous and illuminated by moving away landing lamps of textural cues is imitated in night scenes

◉ Pictures are depicted with respect to given season, the time of day, time belt, date and time of training exercise at the airport of take-off

◉ Correct pictures of celestial bodies are reproduced (Sun, Moon, Stars)

◉ 3D atmospheric entities are reproduced, in particular: clouds, fog, precipitation (snow, rain). Capability to select or change of cloud coverage, density, upper and lower edge of clouds is present.

Visualization database content

◉ Actual size of ground sites – 300x300 km.

◉ Landscape and objects resolution at the airport zone (airfield, helipads) – at least 0,1 m/pixel

◉ Adjacent grounds in 15 km around airports consist of underlying terrain textures with resolution at least 2 m/pixel

◉ Other adjacent 300x300 km grounds are generated with resolution of at least 5 m/pixel

◉ Detailed helipads with resolution (texture quality) of 0,1 m/pixel and 1 km adjacent areas with underlying terrain textures with resolution at least 2 m/pixel are accommodated within territory with dimensions of 300x300 km

◉ At least 5 moving air objects are imitated simultaneously

◉ Visualization system provides the following characteristics of projected real-time pictures of ambient environment on the dome screen:
  ✓ resolution – no more then 3 arc minutes (with regard to pilot's eyes)
  ✓ picture contrast - at least 8:1
  ✓ image brightness - at least 8 ft-lambert
  ✓ levels of detailed images - at least 10
  ✓ projected images frequency - 60 Гц
  ✓ imitated effects general time delay visualization - no more then 100 milliseconds.

◉ Visualization system provides:
  ✓ reproduction of detailed models of 17 airdromes and airfields, 2 training areas, 4 helipads with resolution of 0,1 m/pixel and 16 km adjacent terrain with resolution of 1 m/pixel
  ✓ reproduction of the rest country territory with resolution at least 5 m/pixel

◉ Visual system content includes detailed models of **2 airdromes and airports, 2 training areas, and 4 helipads**

Calculations of visual system characteristics

Dome screen (R-5m) continuous coverage calculation data with use of **4K Type** projectors to meet EASA visual quality requirements
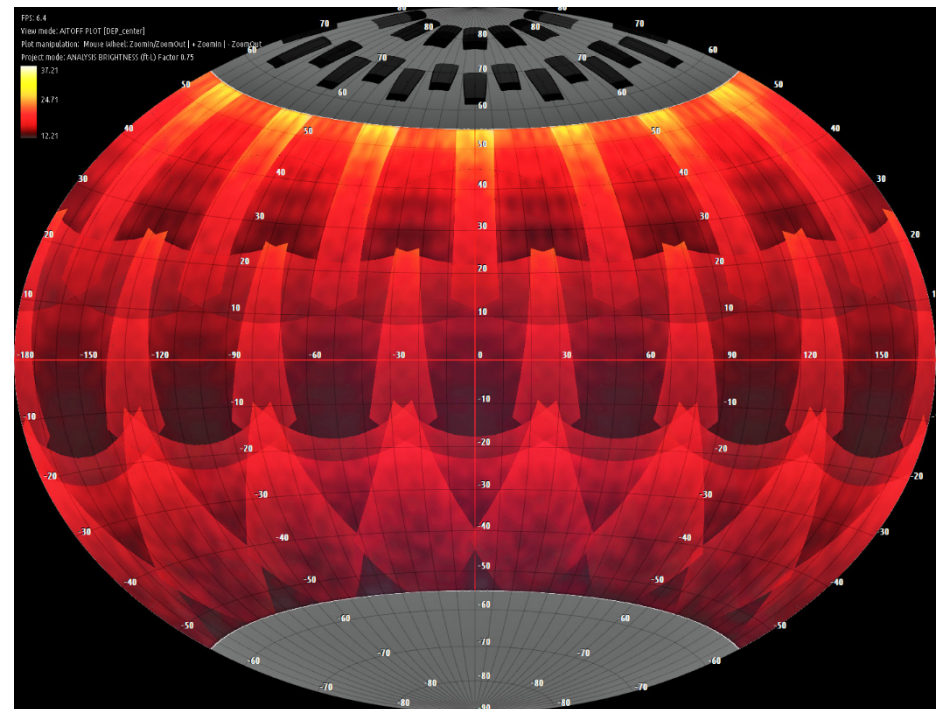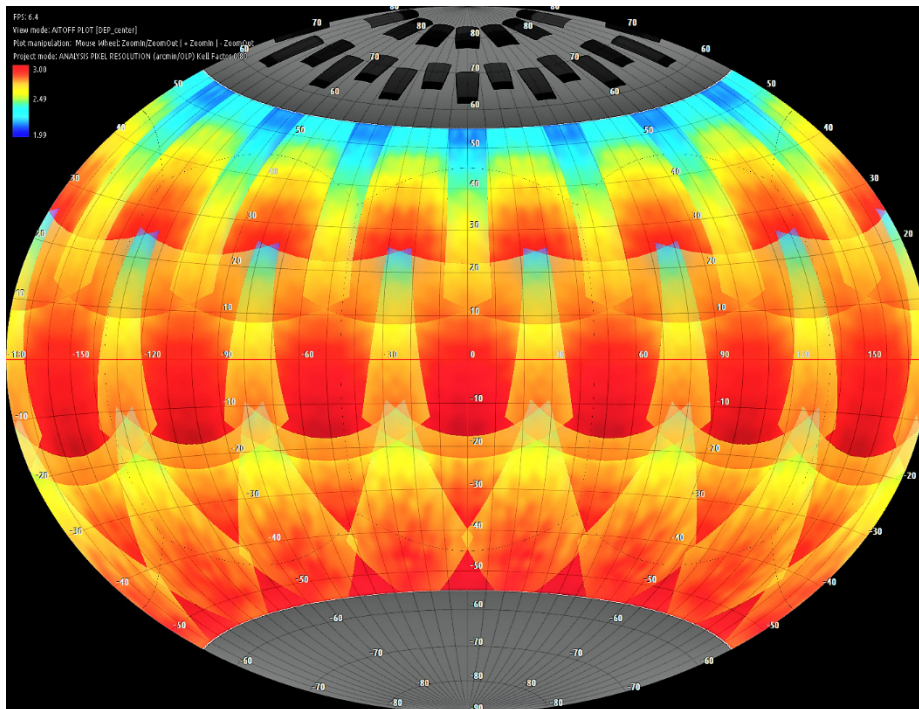
- Quantity of projectors – 21
- Image vertical angular dimension – 110 degrees
- Image horizontal angular dimension – 360 degrees
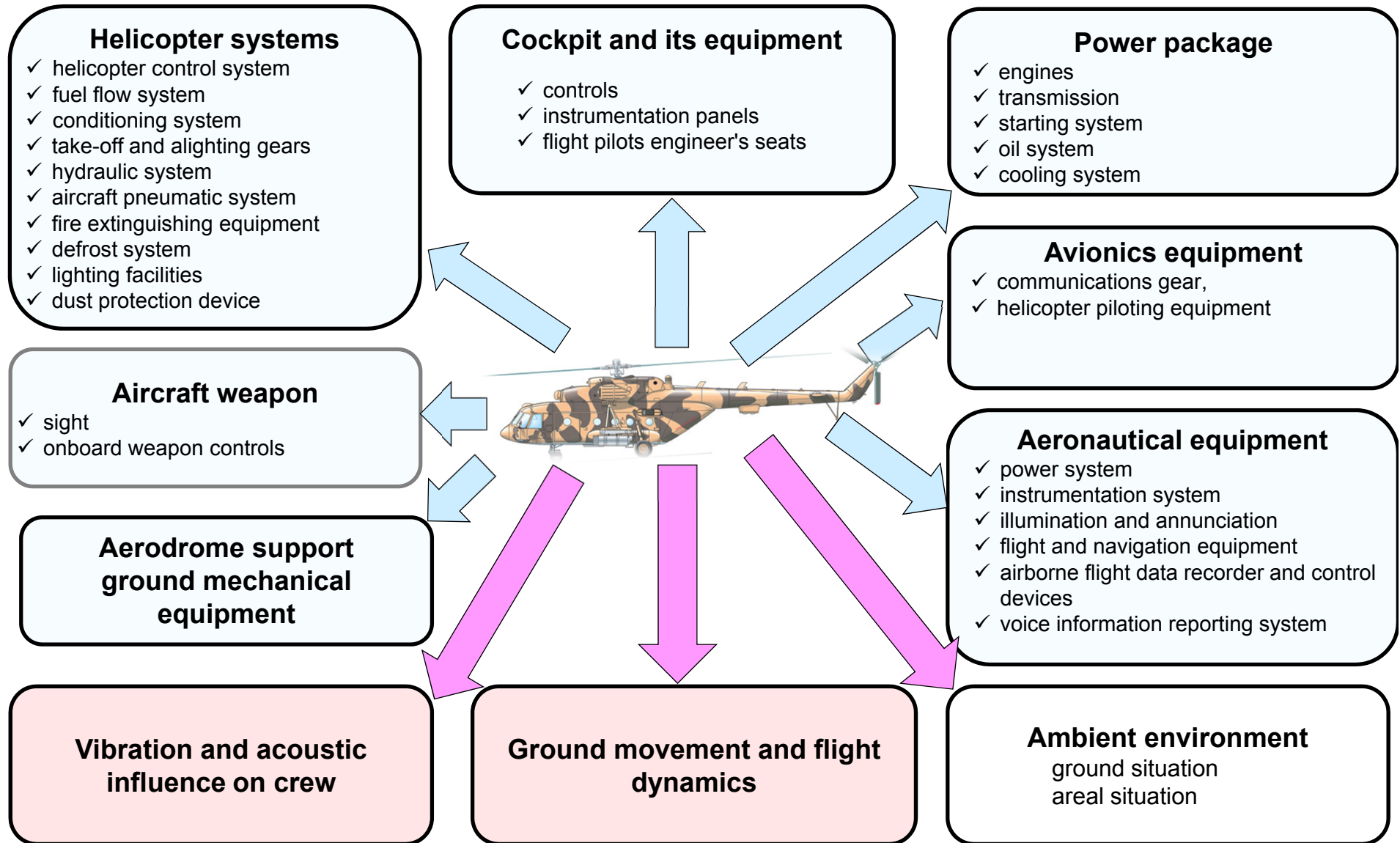
Image resolution calculations

- ✓ Image maximum resolution = 1,99 arcmin/OLP
- ✓ Image minimum resolution = 3,00 arcmin/OLP

Image brightness calculations
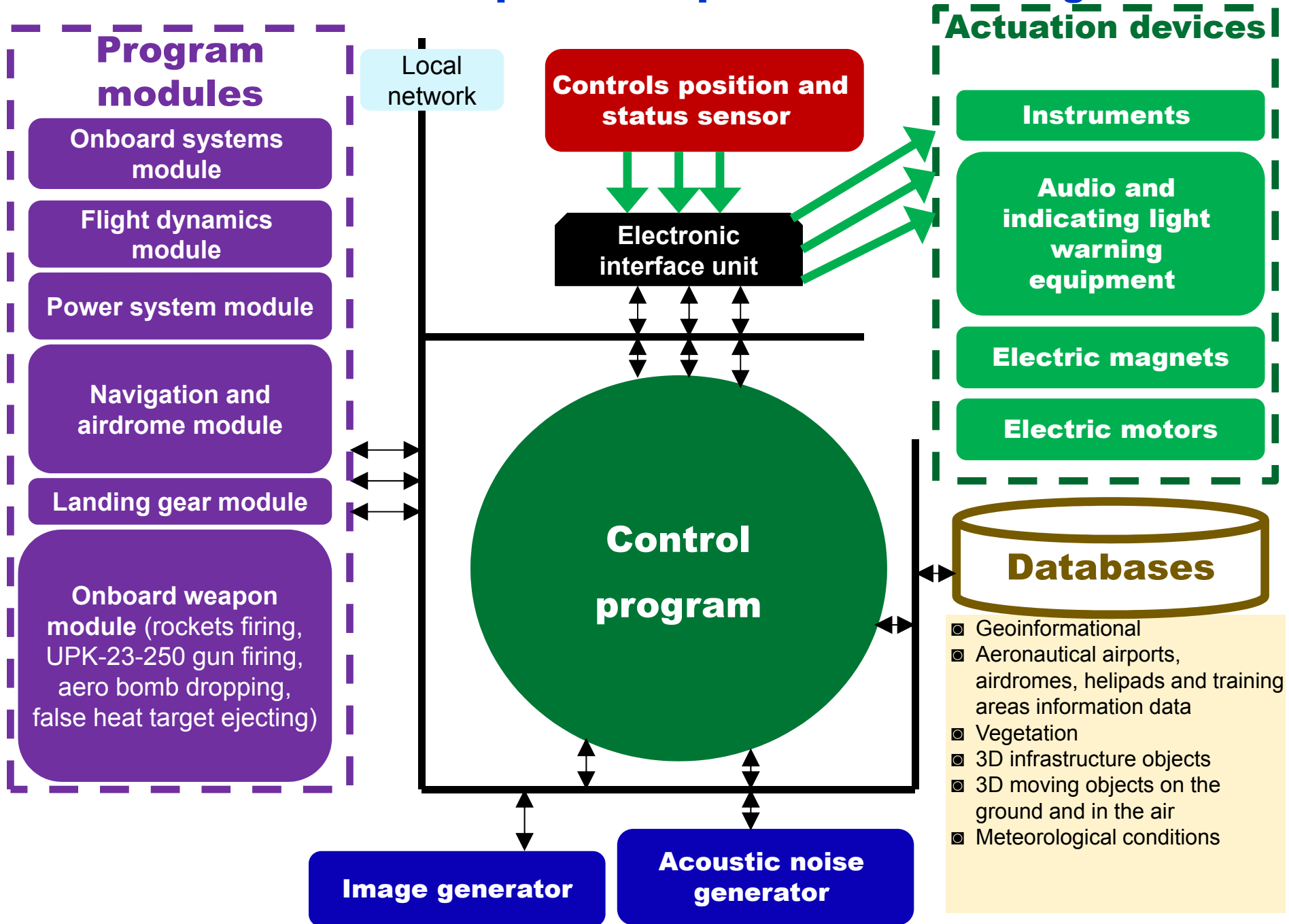
- ✓ Image maximum brightness = 37,21 foot-lambert
- ✓ Image minimum brightness = 12,21 foot-lambert

Objects and processes of helicopter simulation

Helicopter systems
- ✓ helicopter control system
- ✓ fuel flow system
- ✓ conditioning system
- ✓ take-off and alighting gears
- ✓ hydraulic system
- ✓ aircraft pneumatic system
- ✓ fire extinguishing equipment
- ✓ defrost system
- ✓ lighting facilities
- ✓ dust protection device

Cockpit and its equipment
- ✓ controls
- ✓ instrumentation panels
- ✓ flight pilots engineer's seats

Power package
- ✓ engines
- ✓ transmission
- ✓ starting system
- ✓ oil system
- ✓ cooling system

Avionics equipment
- ✓ communications gear,
- ✓ helicopter piloting equipment

Aircraft weapon
- ✓ sight
- ✓ onboard weapon controls

Aeronautical equipment
- ✓ power system
- ✓ instrumentation system
- ✓ illumination and annunciation
- ✓ flight and navigation equipment
- ✓ airborne flight data recorder and control devices
- ✓ voice information reporting system

Aerodrome support ground mechanical equipment

Vibration and acoustic influence on crew

Ground movement and flight dynamics

Ambient environment
ground situation
areal situation

Software and computer complex structural diagram

Program modules
- Onboard systems module
- Flight dynamics module
- Power system module
- Navigation and airdrome module
- Landing gear module
- Onboard weapon module (rockets firing, UPK-23-250 gun firing, aero bomb dropping, false heat target ejecting)

Local network

Controls position and status sensor

Electronic interface unit

Control program

Actuation devices
- Instruments
- Audio and indicating light warning equipment
- Electric magnets
- Electric motors

Databases
- ◙ Geoinformational
- ◙ Aeronautical airports, airdromes, helipads and training areas information data
- ◙ Vegetation
- ◙ 3D infrastructure objects
- ◙ 3D moving objects on the ground and in the air
- ◙ Meteorological conditions

Image generator

Acoustic noise generator

Simulator software suite

Helicopter flight dynamics modelling (on the ground and in the air) is performed on a real time basis with respect to flapping motion of lifting and steering rotor blades, both within operation range of airspeed-altitude envelope, and special flight procedures (ring vortex of lifting and steering rotor, "pick-up", "roll-off", steering rotor, and engines failure). Helicopter aerodynamic characteristics are calculated close-to-ground (ground effect) with respect to particular area terrain features (plain, desert, cross-country, mountain, water surface). External load is modeled (on pylons) based on helicopter reaction on cargo drop-off method and helicopter weight change (smooth – under fuel running out, stepped - ammunition ejection).

External wind perturbations and ambient conditions are set and correctly accounted in accordance with accepted standards.
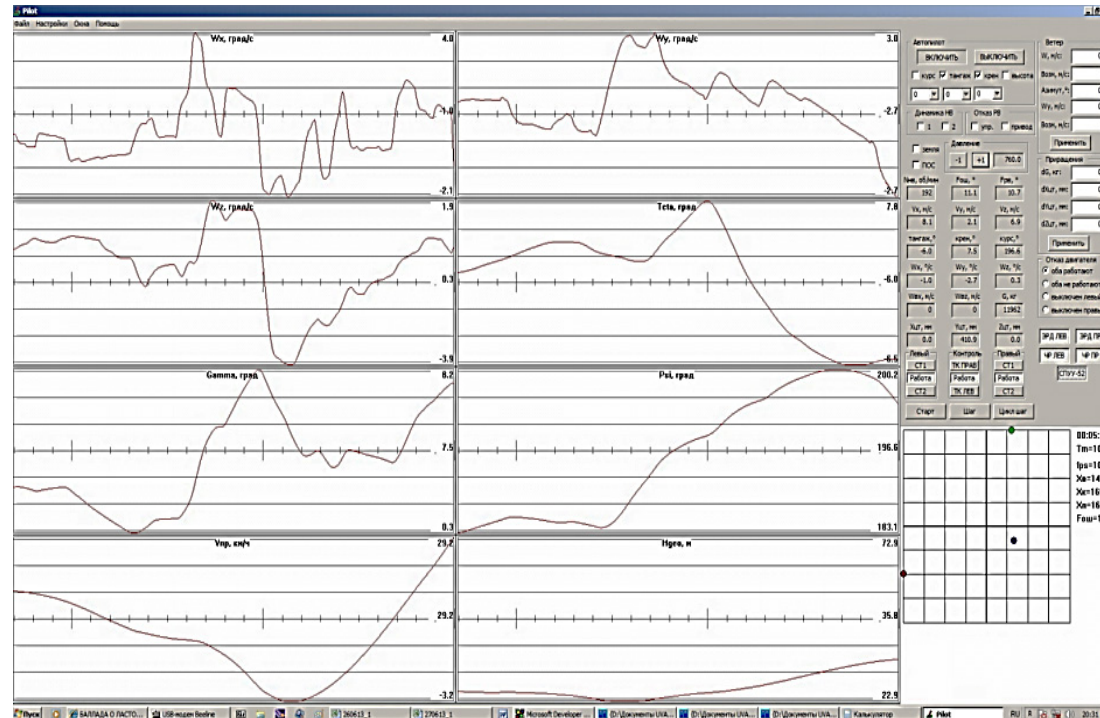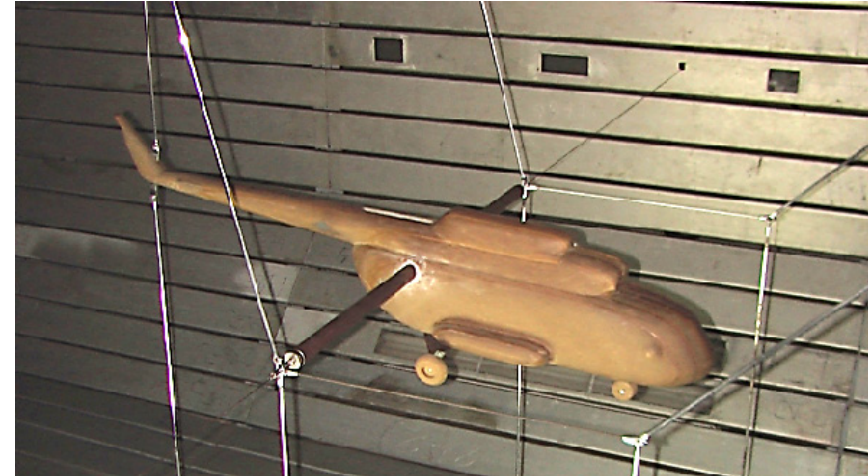
Simulator software suite structural diagram
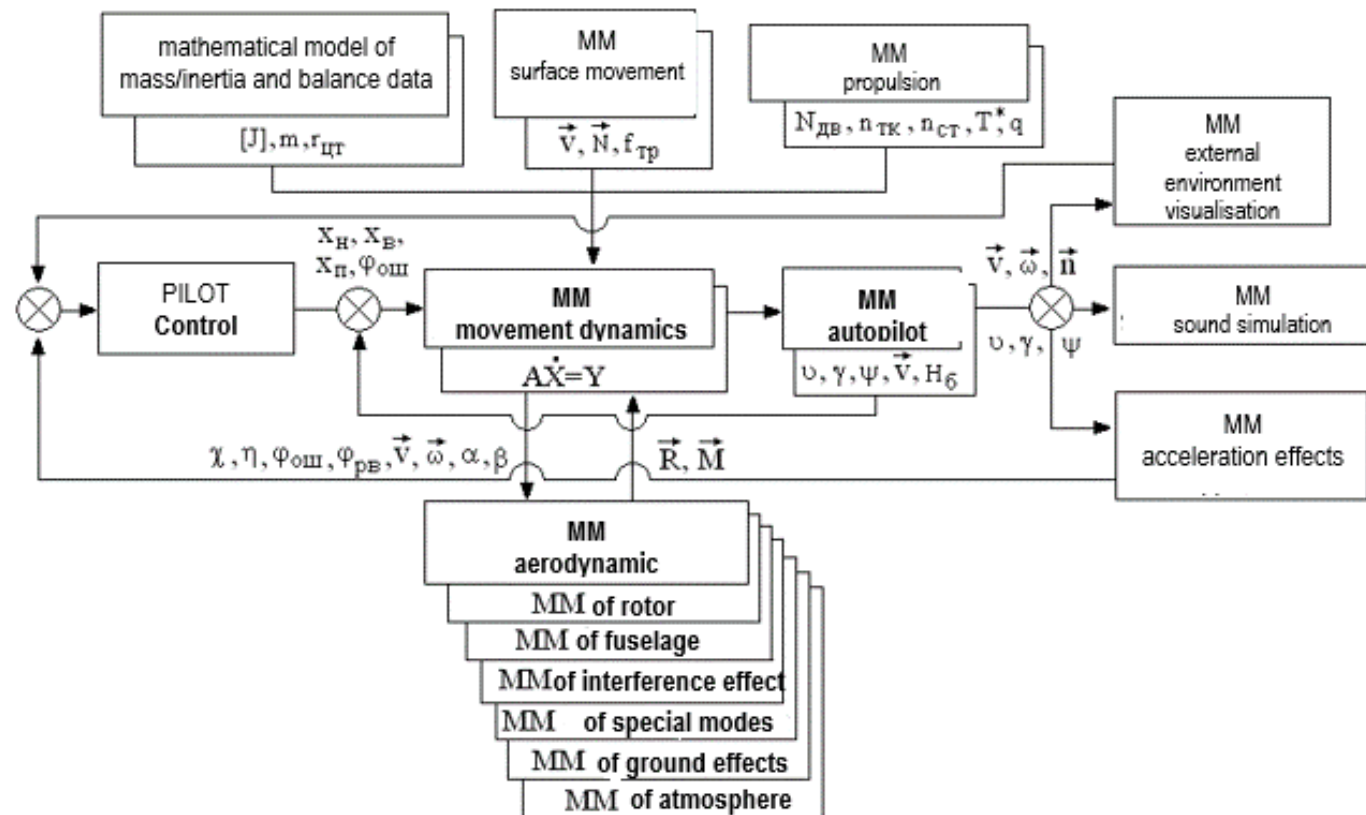
Helicopter flight mathematical model

Aerodynamic analysis of Mi-17B-5 helicopter scale model in air tunnel was conducted in order to enhance adequacy of flight mathematical model. Aerodynamic circular data of helicopter airframe was received.

Simultaneous helicopter-prototype verification flights was conducted in order to identify flying qualities within operational range of flight altitude and speed.

Consequently, essential database was received to verify flight mathematical model.

Instructor's work station

Main menu view to conduct AAR

Instructor's work place *(inside of cockpit mockup cargo area)* and remote Instructor's work station

Instructor's work station

- ◘ Selection sector of the terrain from the simulator library in accordance with training plan and complexity level
- ◘ Selection of training scenario
- ◘ Exercises development and editing
- ◘ Real-time trainee's action supervision
- ◘ Crew-instructor two-ways communications

Simulator On/Off and status monitoring

Flight results evaluation

Results printing

Saving results in database

Injection of imitated onboard systems failures (malfunctions) and abnormal situations

Mode selection: «reset», «record», «playback»

Instructor's training capabilities (before and during exercise conduct)
- ✓ selection of area for upcoming flight assignment from pre-set geoinformational database
- ✓ flight assignment setting: mission, combat payload, itinerary and flight profile
- ✓ meteorological conditions setting
- ✓ flight operations director's functions carrying out
- ✓ running modifications of current training scenario (injecting of abnormal, emergency situations, and equipment failure etc.)
- ✓ displaying of current helicopter position within virtual combat environment on electronic ground map
- ✓ two-ways intercommunicating with crew members
- ✓ supervision and training event managing with ability to suspend, subsequent analysis of trainee's (crew members) actions
- ✓ flight mission progress records keeping
- ✓ all trainee's results saving and crew members actions analysis
- ✓ training results printing

Simulator infrastructure

- Hangar (framed structure) with space of 200-250 sq.m and height of 10-12 m, fitted with entry line, roller-type gate with width of 4 m and height of 6 m, telfer, ventilation and conditioning systems, power supply feed circuit breaker panel, electric lighting, earthing loop, concrete basement for motion system with 1 m depth, technical staff room, instructor's room, crew's room, AAR (post-flight analysis) room.
- Server room with conditioning system
- Simulator power and control cables
- Simulator uninterruptible power system
- Cockpit ventilation and conditioning system
- Main and backup electrical power system
- Additional auxiliary electrical power unit
- Dome screen with assembly frames
- Projectors hanging structural elements, equipped with platforms for projector's maintenance

Simulator adequacy

Simulator ensures assigned adequacy due to achievement of high level design and functional adequacy both of its separate elements, and entire product during simulator manufacturing

Design adequacy is achieved due to:

- Full compliance of geometric dimensions of cockpit simulator and location of nodes and equipment mockups;
- Maximal similarity of frontal instrument panels and equipment (devices) mockups to real ones;
- Correspondence of equipment, scales, displays and plates (shields) illumination to those of imitated helicopter.

Functional adequacy is achieved due to:

- Correspondence of on-board systems, devices and node's mockups functioning algorithms, and, consequently, controls reactions and indications on crew member's control inputs;
- Reproducing of full range of control procedures, required for all main functions execution during preparation for and in the course of flight;
- Ensuring of correspondence of real travel ranges, forces, and reactions of pilot controls (pedals), and switches in cockpit simulator;
- Computation and visualization of helicopter flight trajectory in accordance with detailed flight model and meteorological conditions;
- Computation and visualization of air-launched weapon's trajectory in accordance with its characteristics;
- Realistic imitation of sound effects of operating nodes and equipment, as well as atmospheric effects.

Simulator reliability

Simulators reliability program is based on following principles:

- Use of proven by exploitation, the best quality and reliable components together with their incoming control
- Program solutions development that exclude conflicts between specific and general software, as well as conflicts between software and hardware elements
- Multiple repeated check of design solutions that provide long-term lifecycle of mechanical nodes
- Functional and phased check of quality of mechanical and electrical simulator assembly
- Exclusive usage of non contacting angle of rotation sensors (based on magneto sensitive microchips)
- Usage of protective means of print boards of electronic devices and connectors from environmental affects
- Usage of industrial computers
- Usage of uninterrupted power supply units
- Providing of required simulator hardware thermal conditions
- Providing power margin of power supply equipment

Warranty and life-cycle

- ▶ Simulator's warranty is 3 years under conditions of strict adherence of exploitation and maintenance rules in accordance with operating instructions
- ▶ Simulator's lifecycle is not less than 20 years under conditions of strict adherence of exploitation and maintenance rules in accordance with operating instructions

® Daily non-stop operation is 12 hours

® No-failure operating time is not less than 1000 hours

Operating characteristics

№	Parameter name		Measurement	Parameter value
1	The type of training facility		---	Preferably, training facility should be located at the first floor of fundamental structures or easy-to-assemble facility type
2	Minimum area of training facility		m²	216 (12x18 m)
3	Minimum height	Static screen and dynamic cabin	m	10
		Screen and cabin mounted on dynamic platform		16
4	Actuation time		min	not more than 15
5	Daily running time		hours	not less than 12
6	Power supply: voltage		V	220±10%
	frequency		Hz	50±1
7	Maximum consumed power		kW	55
8	Increased operating and limiting temperature		°C	Up to +35
	Lowered operating temperature			Up to+5
9	Relative humidity at a temperature of +25°C		%	Up to 80 mm Hg
10	Diagnostic system		---	In-built semi-automatic
11	On/Off control		---	From Instructor's work station
12	SPTA		---	Individual
13	Trainees and operating personnel electro safety		---	Dangerous voltage exclusion (direct voltage used + 24 V). Short-circuit protection
14	Simulator hours in service accounting			Operating hours program counter
15	Assembled simulator weight, no more than		kg	3600
16	Operating documentation		---	Logbook, Operating Manual, On-site assembly and adjustment Manual, SPTA Set List

Training and methodological capabilities of the simulator

Simulator allows to practice:

✓ Basic helicopter flying skills under normal equipment operating, normal and difficult meteorological conditions at the following stages:
- flight preparation and equipment check before engines start;
- engines start (AI-9B, TVZ-117B);
- taxiing-out;
- take-off;
- hovering;
- climbing;
- cruise flight;
- different flying modes maneuvering;
- decent;
- landing approach;
- touch-down;

✓ Instrumental flight;
✓ aerial surveillance;
✓ flying against different terrain relief background;
✓ flying under day and night conditions;
✓ flying under summer and winter conditions;
✓ regular flight operation mode crew procedures;
✓ crew procedures to localize airborne equipment failures;
✓ crew coordination procedures;
✓ navigation and instrumental flying problem solving under real air navigation conditions with use of upgraded, delivered with simulator databases;
✓ radio communication skills between air movement control bodies;
✓ helicopter on-board systems operating skills;
✓ flight procedures under abnormal and emergency conditions;

Additional tasks performed with helicopter in transport-combat configuration:

- search, detection, identification and recognition of ground targets;
- combat maneuvering and ground target engagement with imitated airborne weapon firing;
- external environment adaptation with use of night vision goggles OBH-1 type under night flying conditions
- on-board safeguarding (protection) equipment control (false heat target ejector etc.)

Simulator's capabilities to create specific (abnormal) situations in order to practice emergency flight procedures

- lifting and control rotor vortex-ring state
- take-off and landing on dusty and snow-covered grounds
- hedgehopping over cross-country terrain
- landing on unprepared ground, selected from the air
- small-scale ground landing
- landing at lifting propeller autorotation mode
- critical systems and equipment failure

- Airborne auxiliary power failure
- Engine-control system failure
- Increased dangerous engine vibration
- IB-500 system failure
- Engine oil pressure drop
- Oil temperature raise or chippings occurrence in engine oil
- Gear-reduction box failure
- Fuel flow system failure
- Primary hydraulic system failure
- Horizon indicator failure
- Aircraft electrical failure

- Engine bay (right or left) fire
- Main gear box fire
- Heater bay fire
- First priority mechanization failure
- One engine failure
- Both engines failure
- Generators failure
- Directional actuator system malfunction
- Defrost system malfunction
- Radio Navigational Aids malfunction
- Instrumentation system malfunction

Use of simulator in helicopter units flight training process

CAPABILITIES

Safe and easy practicing of crew member's functional flight procedures compering to real flight. Recurring flight procedures and helicopter's tactical employment training in accordance with Mi-17 Rotorcraft Flight Manual

REALISM

Simulator replicates flight with high level of realism due to use of 6DOF motion system, dome screen and realistic ambient environment visualization system. Acceleration, vibration, and acoustic effects are imitated with high level of adequacy when flight is conducted with use of simulator

SAFETY

Capacity to imitate abnormal (emergency) situations, which is impossible or extremely risky to create during real flight in order to train crew to cope with

OBJECTIVENESS

Simulator allows detailed flight mission analysis, as well as analysis of selected flight procedures carried out by each crew member

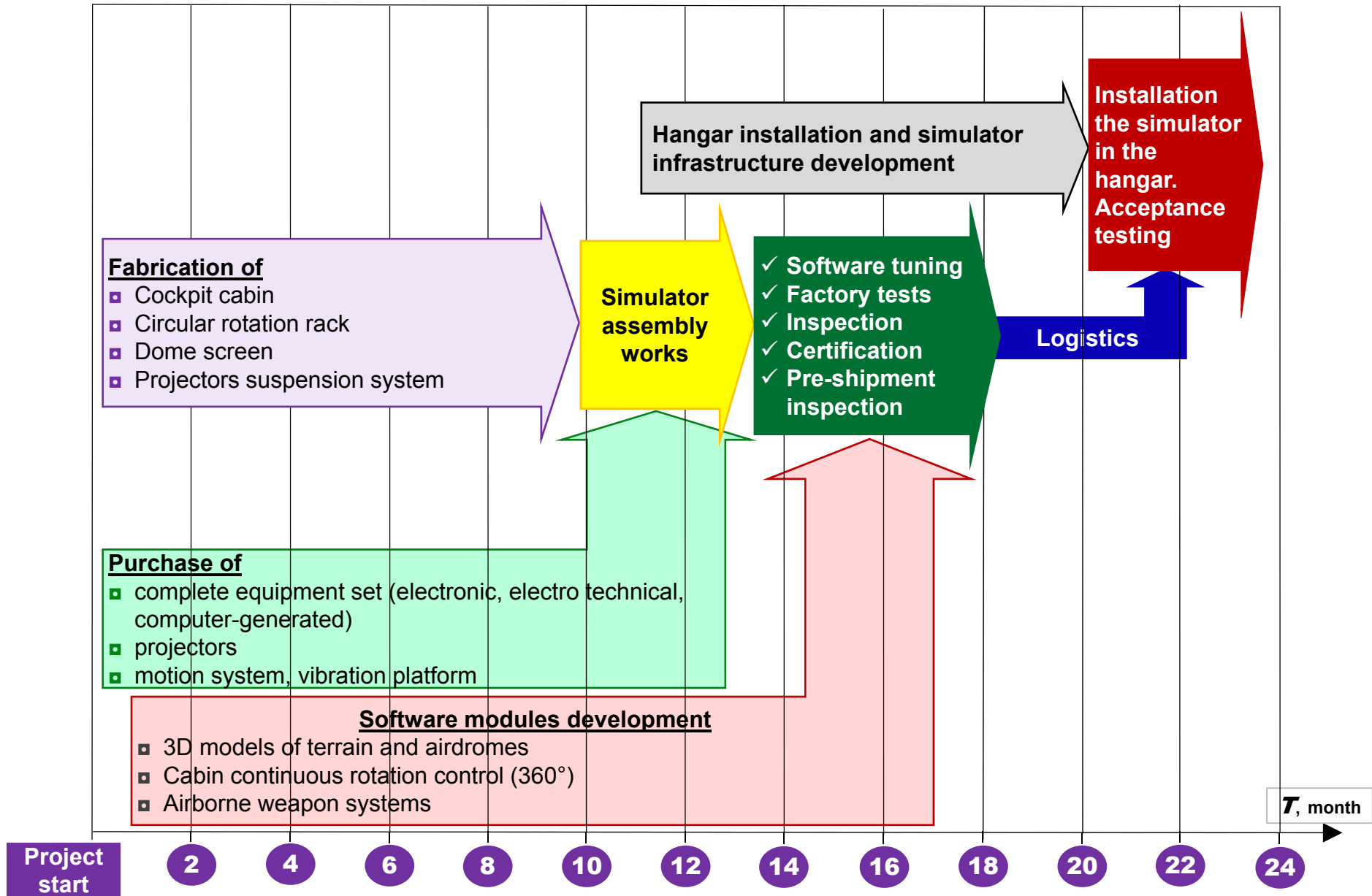## RELIABILITY

Simulator can be used for 12 hours daily without reference to real meteorological conditions

COST EFFECTIVENESS

Expenses are far less when simulation is used then real helicopter is used for training purposes

Simulator delivery schedule in version when screen is static and cabin is mounted on the motion system (with continuous yaw rotation, 360°)

Hangar installation and simulator infrastructure development

Installation the simulator in the hangar. Acceptance testing

Fabrication of
- Cockpit cabin
- Circular rotation rack
- Dome screen
- Projectors suspension system

Simulator assembly works

- ✓ Software tuning
- ✓ Factory tests
- ✓ Inspection
- ✓ Certification
- ✓ Pre-shipment inspection

Logistics

Purchase of
- complete equipment set (electronic, electro technical, computer-generated)
- projectors
- motion system, vibration platform

Software modules development
- 3D models of terrain and airdromes
- Cabin continuous rotation control (360°)
- Airborne weapon systems

T, month

Project start   2   4   6   8   10   12   14   16   18   20   22   24

Simulator delivery schedule in version when screen and cabin as a whole are mounted on the motion system

Hangar installation and simulator infrastructure development

Fabrication of
- cockpit cabin
- dome screen
- projectors suspension system

Simulator assembly works

✓ **Software tuning**
✓ **Factory tests**
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Logistics

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- projectors, motion system
- vibration platform

Software modules development
- 3D models of terrain and airdromes
- Airborne weapon systems

T, month

Project start

2   4   6   8   10   12   14   16   18   20   22   24

Mi-17 helicopter flight simulator designer and manufacturer provides:

✓ Manufacturing and shipping (delivering) of simulator to the point of use

✓ Assembly works, operational commissioning tests

✓ Training of customer's technicians

✓ Warranted maintenance

✓ Post warranted maintenance

✓ Author's supervision and modernization of simulator's hardware and software during whole period of simulator operations