



TÜBİTAK

**SAGE**

DEFENSE INDUSTRIES RESEARCH AND  
DEVELOPMENT INSTITUTE

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# TÜBİTAK SAGE

## DEFENSE INDUSTRIES RESEARCH AND DEVELOPMENT INSTITUTE

Scientific and Technological Research Council of Turkey Defense Industries Research and Development Institute (TÜBİTAK SAGE) was founded in 1972 in order to meet the needs of Turkish Armed Forces and the national defense industry organizations. TÜBİTAK SAGE operates in Ankara, in three different locations; Lalahan, Beşevler and METU Campus.

The vision of the institute is to make Turkey independent in defense technologies.

The mission of the institute is to provide defense industry with competitive and high-added value technologies, products and services through R&D activities.

The main objective of TÜBİTAK SAGE is to make applied research and technological development, in order to contribute in establishing a healthy national defense industry based on scientific and technological principles within the country.

The main mission of institute within the frame of this goal; is to conduct research and development studies to fulfill the requirements of Turkish Armed Forces and national defense industries organizations by establishing cooperation with national and/or foreign foundations when needed.

TÜBİTAK SAGE is empowering its knowledge by research projects, designing and developing software&hardware by development projects, providing services by analysis/measurement and consultancy projects and establishing the infrastructures which are required by the high-tech products and services.

TÜBİTAK SAGE executes projects with Ministry of National Defense, Turkish Armed Forces, Presidency of Defense Industries and various defense industry organizations.





## Historical Development

TÜBİTAK SAGE was established in 1972 in Ankara. Since 1993, TÜBİTAK SAGE has been conducting its activities in Lalahan Region, Ankara with its headquarters and main R&D buildings.

TÜBİTAK SAGE operates in Ankara, in three different locations;

- Lalahan (Headquarters, R&D buildings and test infrastructures)
- Beşevler Ankara Wind Tunnel
- Guidance Control Lab. in Middle East Technical University (METU) Campus

## Fields of Activities

- Execute development projects in the area of guided and unguided munition systems / subsystems
- Perform technology development studies
- Accumulate know-how, form infrastructure and specialized work force
- Produce strategic system and subsystems
- Perform software development activities in areas of specialization (fire command and control, flight simulations, etc.)
- Development and deployment of strategic infrastructures for defense technologies
- Offer inspection, measurement and consultancy services

## Products/Services

- Guided and Unguided Munition Systems/Subsystems
- Strategic Systems and Subsystems
- Software Development
- Analysis and Measurement Services
- Consultancy Services

## Mission

The mission of TÜBİTAK SAGE is “To provide defense industry with competitive and high-added value technologies, products and services through R&D activities.

## Vision

The vision of TÜBİTAK SAGE is “To make Turkey independent in defense technologies”.





# SYSTEM LEVEL PRODUCTS



## **TOROS** ARTILLERY ROCKET SYSTEM

TOROS-230 with a range of 65 km and TOROS-260 with a range of 110 km were developed by TÜBİTAK SAGE. TOROS has a conventional warhead and solid propellant rocket engine.



TOROS consists of sub-systems;

- Launcher vehicle based on 6x6 truck chassis
- Logistics vehicle
- Maintenance vehicle
- Fire command control vehicle, based on a 4x4 vehicle

TOROS-230 ordnance consists of six TOROS-230 unguided medium range rockets in a disposable launcher pod. On the other hand, TOROS-260 ordnance consists of four TOROS-260 unguided long range rockets in disposable launcher pod.

## CAPABILITIES

- TOROS can fire at targets both at very short and very long ranges (20-110 km).
- TOROS can destroy a wide variety of targets thanks to its highly effective modern warheads.
- TOROS has high firepower. The system can be used day and night on any terrain and weather conditions. TOROS is a highly mobile and flexible weapon system.

## OPERATIONAL CONCEPT

TOROS fulfills the fire supports needs for close combat and deep operations. TOROS fills the gap in between field artillery and tactical ballistic missile. TOROS destroys the enemy's critical and high value tactical/operational/strategic targets such as combat force, reserves, concentration areas, logistic infrastructures, command and control centers, choke areas, air defense sites, missile batteries, intelligence facilities, airports, ports, industrial facilities, political and economical centers.

- TOROS crew can move the launcher into position, orient the launcher to the target, fire the rockets and leave the launch position without leaving the cab.
- TOROS has high survivability: TOROS shoots and scoots.
- TOROS launcher is simply operated by a few personnels.



## **SOM-A / SOM-B1 / SOM-B2 / SOM-J** **STAND-OFF MISSILE**

Stand-Off Missile (SOM) is an air-to-surface Cruise Missile with turbojet engine designed to be used against heavily defended land and sea surface targets. SOM provides the capability of destroying designated military targets with high accuracy with the launching aircraft remaining outside the effective range of hostile air defense systems.

SOM-A and SOM-B1 have been in Turkish Air Force (TurAf) service since 2011. Work for developing other variants, SOM-B2 which has Dual Stage Tandem Penetrating Warhead and SOM-C1 & SOM-C2 which have ASuW and datalink capability, are ongoing.

## SOM-A MISSILE

- Missile Weight ~ 1350 lb.
- It is the first variant of Stand of Missile Family
- High explosive blast-fragmentation warhead
- Global Positioning System (GPS)
- Inertial Navigation System (INS)
- Terrain Referenced Navigation (TRN)

## SOM-B1 MISSILE

It is designed against soft targets such as SOM-A and differently it has Infrared Imaging (IIR) seeker.

- Missile Weight ~ 1350 lb.
- High Explosive Blast-Fragmentation Warhead
- Global Positioning System (GPS)
- Inertial Navigation System (INS)
- Terrain Referenced Navigation (TRN)
- Imaging Infrared (IIR) Seeker
- Automatic Target Acquisition (ATA)

## SOM-B2 MISSILE

SOM-B2 is designed against hard concrete targets. Differently from SOM-A and SOM-B1 it has Dual Stage Tandem Penetrating Warhead.

- Missile Weight ~1450 lb.
- Dual Stage Tandem Penetrating Warhead
- Global Positioning System (GPS)
- Inertial Navigation System (INS)
- Terrain Referenced Navigation (TRN)
- Imaging Infrared (IIR) Seeker
- Automatic Target Acquisition (ATA)





## SOM-J MISSILE

SOM-J is one of the variants of the SOM Missile System Family specially designed for F-35 Joint Strike Fighter (JSF) internal/external carriage and used against highly defended, anti-access and high value stationary and moving surface (ASuW) and land targets.

- Missile Weight -1000 lb.
- Semi-Armor Piercing Warhead
- Global Positioning System (GPS)
- Inertial Navigation System (INS)
- Terrain Referenced Navigation (TRN)
- Imaging Infrared (IIR) Seeker
- Automatic Target Acquisition (ATA)
- Network Enabled Weapon (NEW) Capability
- Universal Armament Interface (UAI) Compatibility
- Off-Board, On-Board and In-Flight Mission Planning Capability



MISSILE	WARHEAD	GUIDANCE	PLATFORMS	RANGE
<b>SOM-A</b>	HIGH EXPLOSIVE BLAST-FRAGMENTATION WARHEAD	GPS-INS-TRN	F-4E/2020 F-16 Blok 40	250 KM
<b>SOM-B1</b>	HIGH EXPLOSIVE BLAST-FRAGMENTATION WARHEAD	GPS-INS-TRN-IIR SEEKER+ATA	F-4E/2020 F-16 Blok 40	250 KM
<b>SOM-B2</b>	DUAL STAGE TANDEM PENETRATING WARHEAD	GPS-INS-TRN-IIR SEEKER+ATA	F-4E/2020 F-16 Blok 40	250 KM
<b>SOM-J</b>	SEMI-ARMOR PIERCING WARHEAD	GPS-INS-TRN	F-16 F-35	200+ KM

# HGK-82/HGK-83/HGK-84/LHGK-84 PRECISION GUIDANCE KIT



## HGK-82 (Precision Guidance Kit-82)

HGK-82 is a GPS/INS guidance kit that turns existing 500 lb Mk-82 general purpose bombs into air to ground smart weapons which can be released multiple by using BRU 57 ejector rack.

- Multiple release capability by using BRU 57 ejector rack
- Re-targeting during captive flight
- Jam resistant
- Operation in all weather conditions day and night
- Fewer number of bombs, sorties and crews per mission
- Cost effective
- High precision with integrated GPS/INS
- 12 nautical miles range released from medium altitudes
- 15 nautical miles range released from high altitudes
- CEP Value : <10 m with INS/GPS,  
CEP Value : <25m with only INS
- Certified to F-16 PO-III and F-4E/2020 aircrafts
- MIL-STD 1760 compliance





### HGK-83 (Precision Guidance Kit-83)

HGK-83 is a GPS/INS guidance kit that turns existing 1000 lb Mk-83 general purpose bombs into air to ground smart weapons which can be released multiple by using BRU 57 ejector rack.

- Multiple release capability by using BRU 57 ejector rack
- Re-targeting during captive flight
- Jam resistant
- Operation in all weather conditions day and night
- Fewer number of bombs, sorties and crews per mission
- Cost effective
- High precision with integrated GPS/INS
- 12 nautical miles range released from medium altitudes
- 15 nautical miles range released from high altitudes
- CEP Value : <10 m with INS/GPS,  
CEP Value : <25m with only INS
- Certified to F-16 PO-III and F-4E/2020 aircrafts
- MIL-STD 1760 compliance





### HGK-84 (Precision Guidance Kit-84)

HGK-84 is a GPS/INS guidance kit that turns existing 2000 lb Mk-84 general purpose bombs and penetrator bombs into air to ground smart bombs.

- Re-targeting during captive flight
- Jam resistant
- Operation in all weather conditions
- Fewer number of bombs, sorties and crews per mission
- Minimum logistic footprint
- Minimum collateral damage
- Cost effective
- Certified to F-16 PO-III ve F-4E/2020 aircrafts
- 12 nautical miles range released from medium altitudes
- 15 nautical miles range released from high altitudes
- CEP Value : <10 m with INS/GPS,  
CEP Value : <25m with only INS



### LHGK-84 (HGK-84 with Laser Seeker)

LHGK-84 is GPS/INS and laser guidance kit that turns existing 2000 lb Mk-84 general purpose bombs and penetrator bombs into air to ground smart bombs against both stationary and moving targets.

- Re-targeting during captive flight
- Jam resistant
- Operation in all weather conditions
- Fewer number of bombs, sorties and crews per mission
- Minimum logistic footprint
- Minimum collateral damage
- Cost effective Certified to F-16 PO-III ve F-4E/2020 aircrafts
- 12 nautical miles range released from medium altitudes
- 15 nautical miles range released from high altitudes
- Stationary and moving targets
- Laser seeker usage
- CEP Value : <10 m with INS/GPS,  
CEP Value : <25m with only INS





## **KGK-82/KGK-83**

### **WING-ASSISTED GUIDANCE KIT**

KGK is a wing-assisted guidance kit that converts existing unguided 1000 lb Mk-83 and 500 lb Mk-82 general purpose bombs into long-range, air to ground smart weapons. With KGK, the bombs have the capability of precision hitting of target from 100 km range, in all weather conditions, providing aircraft to complete the mission safely without entering into enemy air defense zone.

## Overview of Kit Capabilities

- Extended range with wing assistance
- Operation in all weather conditions day and night
- Capability to hit the target with high-precision with the use of INS / GPS with crypto support
- Certified to F-16 and F-4E/2020 fighter aircrafts
- Selectable impact angle in advance
- Target of opportunity capability
- Ability to follow waypoints
- Compatibility to MIL STD 1760

## Target Hitting Accuracy

- CEP Value : <10 m with INS/GPS,
- Optimized INS performance with Transfer Alignment capability

## Compatibility to Different Kind of Bombs

- Single guidance kit can be used for different kinds of unguided bombs (Mk-82 / Mk-83)

## Future Improvement Plans

- NATO UAI compatibility





# GÖKTUĞ

## AIR TO AIR MISSILE SYSTEMS

Aiming to increase Turkish Air Force's air superiority, development of exemplary Within-Visual-Range (WVR) and Beyond-Visual-Range (BVR) Air to Air missiles to be launched from F-16 aircrafts continues at a great speed.

Two novel missiles are being developed under the program. WVR achieves high maneuverability in short range with Imaging Infrared (IIR) Seeker and BVR employs a state-of-the-art Active Radar Seeker.

Developed by TUBITAK SAGE, GÖKTUĞ BVR and GÖKTUĞ WVR are the first indigenous air-to-air missiles of Turkey. GÖKTUĞ BVR is also the first missile with an Active Radar Seeker developed in Turkey. TUBITAK SAGE, who has broken ground by developing critical systems and transferring these products to the defense industry, achieved a giant step forward for the future development of Air Defense Missiles.



## WITHIN VISUAL RANGE AIR-TO-AIR MISSILE

### Guidance

- High resolution IIR Seeker providing outstanding off-boresight capability
- Advanced counter-countermeasure capabilities
- All-aspect engagement capability

### Thrust & Control

- High thrust – reduced smoke solid propellant technology
- Fully electronic Rocket Motor Arming and Firing System with exceptional safety and reliability
- Superior agility with thrust vectoring

### Warhead

- Unique warhead design for maximum probability-of-kill
- Distinguished safety and reliability with always-in-line fuzing

### Compatibility

- MIL-STD-1553 & MIL-STD-1760 compatible
- Designed for use with LAU-129



## BEYOND VISUAL RANGE AIR-TO-AIR MISSILE

### Guidance

- Novel solid-state active RF seeker technology
- Smart guidance with launch-and-forget capability
- Advanced counter-countermeasure capabilities and home on jamming
- Datalink update capability
- All-aspect & multiple target engagement capability
- Lock on after launch

### Thrust & Control

- High thrust – reduced smoke solid propellant technology
- Fully electronic Rocket Motor Arming and Firing System with exceptional safety and reliability

### Warhead

- Unique warhead design for maximum probability-of-kill
- Distinguished safety and reliability with always-in-line fuzing

### Compatibility

- MIL-STD-1553 & MIL-STD-1760 compatible
- Designed for use with LAU-129



## **NEB-84**

### **PENETRATOR BOMB**

Penetrator Bomb (Turkish abb.NEB), which is the first concrete penetrator system developed in Turkey, is designed to be used against surface and underground targets. NEB contains Multiple War Head Systems (MWS) technology. NEB has similar external geometry, guidance unit interfaces, mass, center of mass and inertia properties with Mk-84 General Purpose Bombs (GPB).

## NEB-84

- High penetration performance even at low impact velocities and angles
- High fragmentation effect against secondary surface targets with pre-formed fragments utilized in Augmenting Charge design
- Programmable fuze delay times
- Usability against various target types
- Potential to be used with all guidance kits which are compatible with Mk-84 (2000 lb) GPB
- Potential to be dropped from all aircrafts which can carry Mk-84 (2000 lb) GPB

## GENERAL PROPERTIES

- Length : 2600 mm
- Maximum Diameter : 457,2 mm
- Weight : 870 kg
- Types of Explosives
  - Augmenting Charge : PBX 110
  - Follow Through Bomb: PBX109
- Fuze
  - Augmenting Charge: ONUR-1MOD4
  - Follow Through Bomb: FMU-152 A/B, TST-101

## GUIDANCE

NEB can be used with Precision Guidance Kit (Turkish abb. HGK) and GBU-10E/B Laser Guidance Kit and has the potential to be used with all guidance kits which are compatible with Mk-84 (2000 lb) GPB.

## PLATFORMS

NEB is certified for F4E/2020 and F-16 fighting aircrafts and has the potential to be dropped from all aircrafts for which Mk-84 (2000 lb) GPB is certified.

## PENETRATION PERFORMANCE

Minimum 2.1 m 35 MPa reinforced concrete

## TYPICAL TARGETS

### Buried Hard Targets

- Munitions Depots
- Underground Petrochemical Depots
- Bunkers
- Aircraft Shelters
- Command / Control Centers

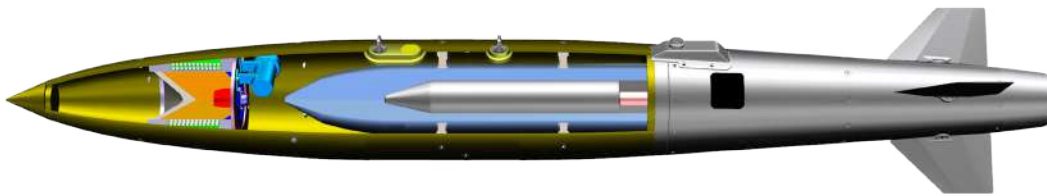
### Surface Targets

- Aircraft Runways
- Dams
- Bridges
- Critical Buildings

### Area Targets

- Radar Antennas
- Stationary Air Defense Missile Sites
- Industrial Facilities
- Parked Aircrafts





## **SARB-83**

### 1000 LB TANDEM PENETRATING BOMB

SARB-83 is a penetrator bomb, which is designed to be used against surface and underground targets. SARB-83 contains Multiple Warhead Systems (MWS) technology. SARB-83 has identical external geometry, guidance unit interfaces, mass, center of mass and inertia properties with Mk-83 GPB.



## SARB-83

- High penetration performance even at low impact velocities and angles
- High fragmentation effect against secondary surface targets with pre-formed fragments utilized in augmenting Charge design
- Usability against various target types
- Potential to be used with all guidance kits which are compatible with Mk-83 GPB
- Potential to be dropped from all aircrafts which can carry Mk-83 GPB

## GENERAL PROPERTIES

- Length : 1860 mm
- Maximum Diameter : 356 mm
- Weight : 415 kg
- Types of Explosives
  - Augmenting Charge: PBX-110
  - Follow Through Bomb: PBX-109
- Fuze
  - Augmenting Charge: ONUR-1 MOD4
  - Follow Through Bomb: FMU-152 A/B, TST-101



## GUIDANCE

SARB-83 has the potential to be used with all guidance kits which are compatible with Mk-83 GPB.

## PLATFORMS

SARB-83 has the potential to be dropped from all aircrafts for which Mk-83 GPB is certified.

## PENETRATION PERFORMANCE

1.8 m 5000 psi reinforced concrete.

## TYPICAL HARD TARGETS

### Buried Hard Targets

- Munitions Depots
- Underground Petrochemical Depots
- Bunkers
- Aircraft Shelters
- Command/Control Centers

### Surface Targets

- Aircraft Runways
- Dams
- Bridges
- Critical Buildings
- Radar Antennas
- Stationary Air Defense Missile Sites
- Industrial Facilities
- Parked Aircrafts



## **SERT-82**

### **500 LB PENETRATING BOMB**

SERT-82 has identical external geometry, guidance unit interfaces, mass, center of mass and inertia properties with Mk-82 GPB.



## SERT-82

- High penetration performance even at low impact velocities and angles
- Usability against various target types
- Potential to be used with all guidance kits which are compatible with Mk-82 GPB
- Potential to be dropped from all aircrafts which can carry Mk-82 GPB

## GENERAL PROPERTIES

- Length : PBX-109 (15 kg)
- Maximum Diameter : 273 mm (0.9 ft)
- Weight : 241 kg (500 lb)
- Explosive : PBX-109 (15 kg)

## GUIDANCE

INS/GPS or Laser  
(HGK-82, GBU-38 or GBU-12)

## PLATFORMS

F-4E/2020, F-16

## PENETRATION PERFORMANCE

1 m (35 MPa reinforced concrete)

## TYPICAL HARD TARGETS

### Buried Hard Targets

- Munitions Depots
- Underground Petrochemical Depots
- Bunkers
- Aircraft Shelters
- Command/Control Centers

### Surface Targets

- Aircraft Runways
- Dams
- Bridges
- Critical Buildings
- Radar Antennas
- Stationary Air Defense Missile Sites
- Industrial Facilities
- Parked Aircrafts



# TENDÜREK

## 500 LB THERMOBARIC BOMB Mk-82-T

### PBP-003 / MK 82-T

PBP-003 is a plastic-bonded thermobaric explosive that contains more than 20% by weight metallic powder. The blast wave formed upon detonation creates more impulse and higher quasi-static pressure in indoor targets (caves, tunnels, bunkers etc.). Moreover, the additional amount of heat generated by burning of metallic powder increases the temperature of the flame and extends total time duration of the flame which enhance the thermal effectiveness of the explosive on targets.

In the scope of TENDÜREK project, a thermobaric explosive (PBP-003) and a thermobaric variant of Mk-82 General Purpose Bomb (Mk-82-T) have been developed.

TNT



THERMOBARIC



CONFINED SPACE TEST

Mk-82



MK 82-T



OPEN SPACE TEST

## GENERAL SPECIFICATIONS

- Enhanced pressure and thermal impact on target
- Highly effective for indoor targets
- Ability to operate under all weather conditions
- High accuracy
- Low maintenance requirement
- Min. 10 years of shelf life

## TYPICAL TARGETS

### Buried and/or Indoor Targets

- Bunkers
- Caves
- Command/Control Centers
- Tunnels
- Aircraft Shelters

## SPECIFICATIONS OF MK82-T

Weight	: 230 kg (500 lb)
Explosive	: PBP003(Thermobaric)
Filling Weight	: ~90 kg
Explosive Density	: > 1.70 g/cm <sup>3</sup>
Detonation Velocity	: > 6500 m/s

## OPERATIONAL SPECIFICATIONS

- Higher Quasi-Static Pressure and Impulse
- Higher and Longer Thermal Effects
- Strong Destructive Effect
- Increase in Total Flame Volume with respect to Conventional Mk-82
- Increase in Total Duration of the Time The Flame Stays Alive with respect to Conventional Mk-82.

## GUIDANCE

Mk-82-T has the potential to be used with all guidance kits (HGK-82, KGK-82, LGK-82, GBU-38 and GBU-58 etc.) which are compatible with Mk-82 General Purpose Bomb

## ONGOING/FUTURE WORKS

Application of PBP-003 to various ammunitions and munitions:

- Other MK Series General Purpose Bombs
- Penetrator Bombs
- Stand-off Munition
- Unmanned Air Vehicle Munitions
- Small Caliber Ammunitions



## **BOZOK**

### LASER GUIDED MINIATURE MUNITION

BOZOK provides effective defense without jeopardizing friendly elements in asymmetric warfare by giving attack capability to Unmanned Air Vehicles (UAV). Due to the light weight and compact design, it brings operational conformability in UAV for which weight is critical. BOZOK with its novel design stands out among rivals by the help of robust operational capabilities.

BOZOK exploits inertial measurement unit for tactical inertial guidance for midcourse. During terminal course, precision guidance is achieved by the semi active laser seeker. At the end of the terminal phase, BOZOK presents large scale anti-personnel effect relying on proximity sensors and optimized target effectiveness.



## PHYSICAL CHARACTERISTICS

- Weight: 16 Kg
- Diameter: 120 mm
- Length: 80 cm

## OPERATIONAL CAPABILITIES

- UAV to Ground
- Against Target of Opportunity and Planned Targets, Anti Personnel
- Platform Environmental Conditions Adaptable
- Multi Launch and Multi Carriage
- Standard and Simplified Interface
- High Performance Target Effectiveness

## GUIDANCE

- Midcourse: Tactical Inertial Guidance
- Terminal Phase: Laser Guidance

## FUTURE DEVELOPMENTS

- Multi Engagement against Target of Opportunity and Planned Targets, Anti Personnel
- Different UAV Weapon Systems Variants
- Different Sub-System Development and Integration





# TOGAN

## AIR LAUNCHED MORTAR MUNITION

A low cost air-to-surface weaponeering solution compatible with NATO 81mm mortars. The light weight modular rack makes it possible to integrate to various small UAV platforms. Multiple ejection rack enables maximum efficient usability on mid-size UAV platforms. Lethality is enhanced via its fragmentation ordnance.

On-board reconrol system allows fast trajectory calculations up to 100Hz and provides precision ring solutions for maximum accuracy. DTED based continuously computed footprint predictions ensure minimum collateral damage.

### GUIDANCE

- Ballistic close range low-level air to surface munition
- Optional near-precision guidance for range correction

### EFFECTIVENESS

- Antipersonnel fragmentation
- Lethal radius >35m
- CEP Value: <10m for the guided variant

### FUZE

- Time/proximity

### MISSION PLANNING

Pc-Based, Trajectory Planning, Footprint Calculations, Metcm (Computer Met Message), Weapon Simulations, Real Time On-board Firing Solutions and Footprint Predictions

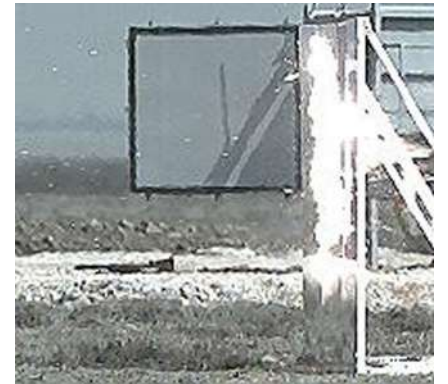
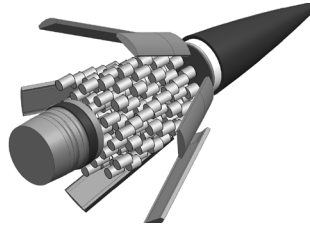
# PARM

## 35 mm AIRBURST AMMUNITION

35 mm Airburst Ammunition (ParM) is deployed against the threats such as air-to-surface missiles, cruise missiles and Unmanned Aerial Vehicles (UAV) crossed the territory defense under the concept of point, air and missile defense.

ParM has the features of airburst ammunition. It forms cloudlike pattern from high density tungsten alloy fragments in order to destroy the target on its path. ParM has an effective range of 4 km. Tungsten heavy alloys for the first time were designed and produced within this ammunition.

ParM is utilized with 35mm Air Defense Guns and KORKUT developed by ASELSAN.







# SUB SYSTEM LEVEL PRODUCTS





## THERMAL BATTERY

Thermal batteries are the ideal energy source to supply the instant and high levels of electrical power requirement of advanced systems. They are widely used as primary power sources in various military and aerospace applications, due to their reliable, maintenance-free and durable structure, as well as their capability of meeting long shelf life requirements. They are for single use (non-rechargeable) and custom designed according to the system's specifications.

Having more than 16 years of experience; to date TUBITAK SAGE has designed and manufactured many different thermal battery types qualified with respect to globally accepted military standards.

Besides being the main supplier of Turkish defense companies, TÜBİTAK SAGE has many worldwide customers with a continuously growing export market.

## MAIN APPLICATIONS OF THERMAL BATTERIES:

- Missiles
- Guidance tail kits
- Acoustic jammers/emulators
- Fuzes
- Guided artillery shells
- Aircraft ejection seat systems



## ADVANTAGES OF THERMAL BATTERIES:

- Long and maintenance free shelf life (>20 years)
- Short activation time (<500 ms)
- Alternative activation methods (electrical igniter, percussion cap, inertial igniter)
- No self-discharge
- High power density
- Simultaneous multiple power supply capacity
- Wide operating temperature range (-54°C/+71°C)
- Durability to extreme environmental conditions (Thermal batteries are durable to high levels of vibration, shock, acceleration, high/low pressure levels, high levels of humidity, etc. during storage and operation)
- High reliability (>%99.95)
- Custom designed (Thermal batteries are designed according to requirements of the main system)



## ATLAS IMU

### INERTIAL MEASUREMENT UNIT

TÜBİTAK SAGE is the leading establishment of Turkey of experience in guided missile technology. ATLAS IMU is a high performance high accuracy IMU. It's electronic hardware designs, software designs, mechanical designs, algorithm and calibration designs were done by TÜBİTAK SAGE.

ATLAS IMU is designed to meet the needs of navigation, guidance and control applications. It provides a very high input range and excellent long-term repeatability.

ATLAS IMU can be successfully used on a wide range of weaponry, military, aerospace, marine and land applications such as stabilized platforms, mission critical platforms, guided missile systems, Unmanned Aerial Vehicles (UAVs). Also, it is suitable for commercial applications. It includes three close-loop fiber optic gyroscopes, three navigation grade quartz Accelerometers and associated electronic and optical designs which are all environmentally sealed in rugged housing. ATLAS IMU has two different variants called as TG (Tactical Grade) and TG+ (High End Tactical Grade).

ATLAS IMU simplifies system integration by offering many configurable features such as data rate output, data communication protocol so that it gives greater flexibility in systems design and integration.

# KÖGAB

## IMAGING INFRARED SEEKER

Imaging Infrared Seeker (KOGAB) is an electro-optical system which includes a long detection range, high resolution infrared imaging system, a high field-of-regard gimbal and state-of-the-art detection and tracking algorithms. KOGAB can be integrated into highly maneuvering missiles to provide precise terminal phase guidance as well as support to navigation systems with an integrated IMU.

KÖGAB has been developed by TÜBİTAK SAGE and has been used within SOM Missile Family.

<b>Seeker Type</b>	Imaging Infrared
<b>Wavelength</b>	Midwave (3.6-4.9 $\mu\text{m}$ )
<b>Detector Resolution</b>	640 x 512
<b>Gimbal Type</b>	Pitch - Yaw
<b>Seeker Length</b>	410 mm
<b>Maximum Diameter</b>	467 mm
<b>Weight</b>	18.5 kg
<b>Shelf Life</b>	10 years
<b>Country</b>	Turkey



# SG-KONUM-01 L1/L2 GPS ANTENNA

## GPS ANTENNA FOR MILITARY SYSTEMS

SG-KONUM-01 is an active GPS antenna developed by TÜBİTAK SAGE operating in L1/L2-GPS and L1-GLONASS bands, which is capable of satisfying military expectations.

SG-KONUM-01 has a geometry which can be easily integrated to relevant military platforms and can operate under harsh environmental conditions like high shock and vibration. The current antenna geometry has been determined by taking into consideration the need of direct integration to the present platforms. The antenna can be designed and manufactured in various geometries according to different weapon or platform requirements. In addition, the antenna architecture can be modified to operate in L5-GPS band.

### OPERATING FREQUENCY

- GPS L1/L2  
L1:1565-1585 MHz L2:1217-1237 MHz
- GLONASS L1

### PERFORMANCE

- Antenna Gain (Passive-Typical) : 4 dBic
- VSWR :  $\leq 2.0 : 1$
- Noise Figure : 3 dB
- Amplified Gain :  $40 \text{ dB} \pm 2 \text{ dB}$

### PHYSICAL CHARACTERISTICS

- Dimensions : 102mm x 96mm x 25mm
- Weight : 290 gr
- RF connector : 50 Ohm SMA Female
- Montage : External

### POWER REQUIREMENTS

- 60 mA @ +5 VDC (Typical)

### ENVIRONMENTAL CHARACTERISTICS (MIL-STD-810G)

- Altitude : > 40,000 m
- Temperature :  $-55^{\circ}\text{C} / +85^{\circ}\text{C}$
- Shock : 40 G
- Vibration : 6 gRMS



# KÂŞIF

## GNSS RECEIVER FOR GUIDED MISSILE SYSTEMS

KÂŞIF is a military grade GNSS receiver which is developed by TÜBİTAK SAGE. It's RF, electronic hardware, software and algorithmic designs were done by TÜBİTAK SAGE.

This receiver has a front-end which supports the usage of GPS L1/L2, GLONASS L1 and GALILEO E1/E5a/E5b signals. The up-to-date firmware and FPGA produces navigation solution only with GPS L1 signals' tracking. The navigation solution will be produced with different combinations of GNSS signals such as, GPS L1 + GLONASS L1 + SBAS, GPS L1 + GPS L2 + SBAS and GPS L1 + GALILEO E1.

### Channel Structure

- GPS: 12 L1 C/A , 12 L2C
- GLONASS: 10 GLONASS L1 C/A
- GALILEO : 12 E1/12 E5a/12 E5b
- SBAS : 2 L1 C/A

### Performance

- Horizontal Accuracy: 5 m (RMS)
- Vertical Accuracy: 7 m (RMS)
- Velocity Accuracy: 0.5 m/s (RMS)
- Warm Start : 25 sec
- Cold Start: 50 sec
- Reacquisition Time: 1 sec

### Physical Characteristics

- Dimensions: 79.7 x 97.1 x 15 mm
- Weight: 250 grams
- RF Connector: MMCX
- Data Con. : TFML-125-02-S-D-A-K-TR

### Interfaces

- RF:
  - a. 5 VDC Active GNSS antenna
  - b. 5 VDC Active GNSS antenna
- Power: 5 VDC, 11 W
- Data: RS-485, 1 Gbps Fast Ethernet

### Environmental Characteristics \*

- Dynamics
  - Velocity: 0-2,000 m/s
  - Acceleration: 15g
  - Altitude Limit:>40,000 m
- Thermal
  - Operating: -40° C to +71° C
- Shock (Operating):  $\pm 20g$
- Vibration: 6 gRMS (MIL-STD-810F)

### Design Standards \*

- RTCA/DO-254
- RTCA/DO-178

### Outputs

- Position and raw data at 1 Hz to 50 Hz



\* Works are in progress.

# SAGE-KONUM-02

## CONTROLLED RECEPTION PATTERN ANTENNA

SAGE-KONUM-02 is an anti-jamming antenna system developed by TÜBİTAK SAGE and TUALCOM. SAGE-KONUM-02 to be used on all platforms is capable of working with any GPS receiver without requiring additional hardware.

CRPA TECHNICAL SPECIFICATIONS	
<b>Weight</b>	<1000 gr
<b>Dimensions</b>	12 cm x 12 cm x 2 cm
<b>Power Consumption</b>	7W
<b>Frequencies</b>	GPS
<b>Typical Wideband suppression</b>	40 dB
<b>Antenna Array</b>	4 Element Antenna Array
<b>Communication Ports</b>	Ethernet, RS485/422, RS-232
<b>Environmental</b>	MIL-STD-810



# CAMGÖZ

## SEMI-ACTIVE LASER SEEKER

CAMGÖZ, which is developed indigenously by TÜBİTAK SAGE, is a long-range, high-angle of sight laser seeker head which is designed for increasing the strike accuracy of general purpose bombs with precision guidance kits in Turkish Air Force inventory and making them suitable for launching against moving targets.



Seeker Type	Semi-active Laser
Operating Wavelength	1064 nm (Compliant with STANAG 3733)
General Attributes	Effective for Fixed or Moving Targets Day&Night Operational Sunlight-resistant National detector design and production (TÜBİTAK BİLGEM) National optical design (TÜBİTAK SAGE) National electronic board design and production (TÜBİTAK SAGE)
Linear Angle of Sight	315°
Extended Angle of Sight	325°
Detection Range	6 km
Seeker Length	170 mm
Seeker Diameter	120 mm
Weight	2,5 kg
Compatible Munition	Weapon Kits with Precision Guidance Kit HGK-84 + MK-84
Platforms	F-4E/2020 F-16
Shelf Lifetime	10 years
Origin	TURKEY



## TST-101 FUZING SYSTEM

TST-101 Fuze is a hard target fuzing system compliant with STANAG 4187 which has been developed for bombs in Air Forces inventory. It is compatible with Turkish Air Force and NATO aircraft and also general purpose bombs and weapon guidance kits.

TST-101 Fuze is adaptable to standard 3" fuze well. The fuze can be triggered internally by impact switch and externally by crush switch or proximity sensor. It has a capability of cockpit programmable arming and firing delays via TIA/EIA-422-B interface compatible with JDAM.

TST-101 Fuze has an out-of-line Safe/Arm and Functioning (SAF) system with high reliability. Its design is suitable for multiple warhead systems. TST-101 Fuze has 10 year service life and 20 year shelf life with operating temperatures between -40 °C and +65 °C.



## TST-201 FUZING SYSTEM

TST-201 Fuze is an in-line fuzing system compliant with STANAG 4187 which has been developed for munitions with rocket propulsion systems.

The fuze can be triggered internally by impact switch and externally by crush switch or firing signal from missile computer. Firing interface of the fuze with mechanical and electronic interfaces can be tailored for specific use. TST-201 has advanced error detection and reporting ability. It can communicate with the platform via TIA/EIA-422-B interface.

TST-201 has a fully electronic Safe/Arm and Functioning (SAF) system. TST-201 Fuze has 10 year service life and 20 year shelf life with operating temperatures between -40 °C and +65 °C.





## **TST-202**

### **ELECTRIC IGNITION SYSTEM FOR ROCKET MOTOR**

TST-202 is an electrical ignition safety device for rocket motors compliant with STANAG 4368 which has been developed to ignite EFI/TBI.

TST-202 has advanced error detection and reporting ability. It can communicate with the platform via TIA/EIA-422-B interface. With the high-speed response time of arming circuit, it is suitable for rocket propellant munition systems aimed to neutralize dynamic targets.

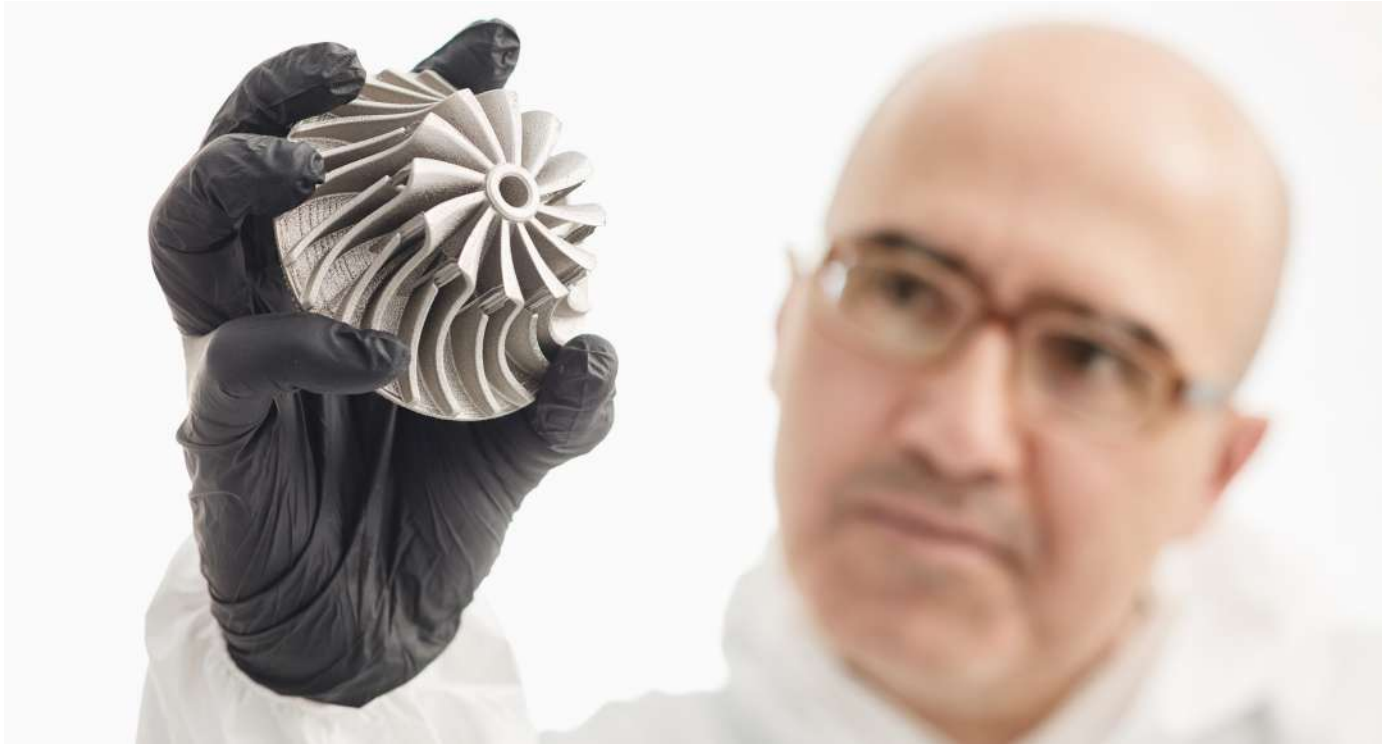
TST-202 has a fully electronic Safe/Arm and Functioning (SAF) system. TST-202 has a service life of 10 years, and shelf life of 20 years with operating temperatures between -40 °C and +65 °C.

## **FUZE INITIATOR**

### **TURBINE GENERATOR**

Fuze initiator turbine generator is a munition sub-system which is functioning with bomb release and capable of deriving energy from the airstream and converting the energy into electric energy and signal suitable for arming the fuze.

Within the scope of developing a general purpose bomb fuze and hard target fuze, fuze initiator turbine generator is aimed to be developed in order to provide the fuze with required power and safe arming signals.



## LASER SINTERING SYSTEM FOR **POLYMER MATERIALS**

### **EOS P396**

Building volume	: (x:y:z) 340 mm:340 mm:600 mm
Laser Type	: 70W CO2 laser
Build Rate	: 32 mm/hour
Layer Thickness	: 120 micrometer

### **Materials:**

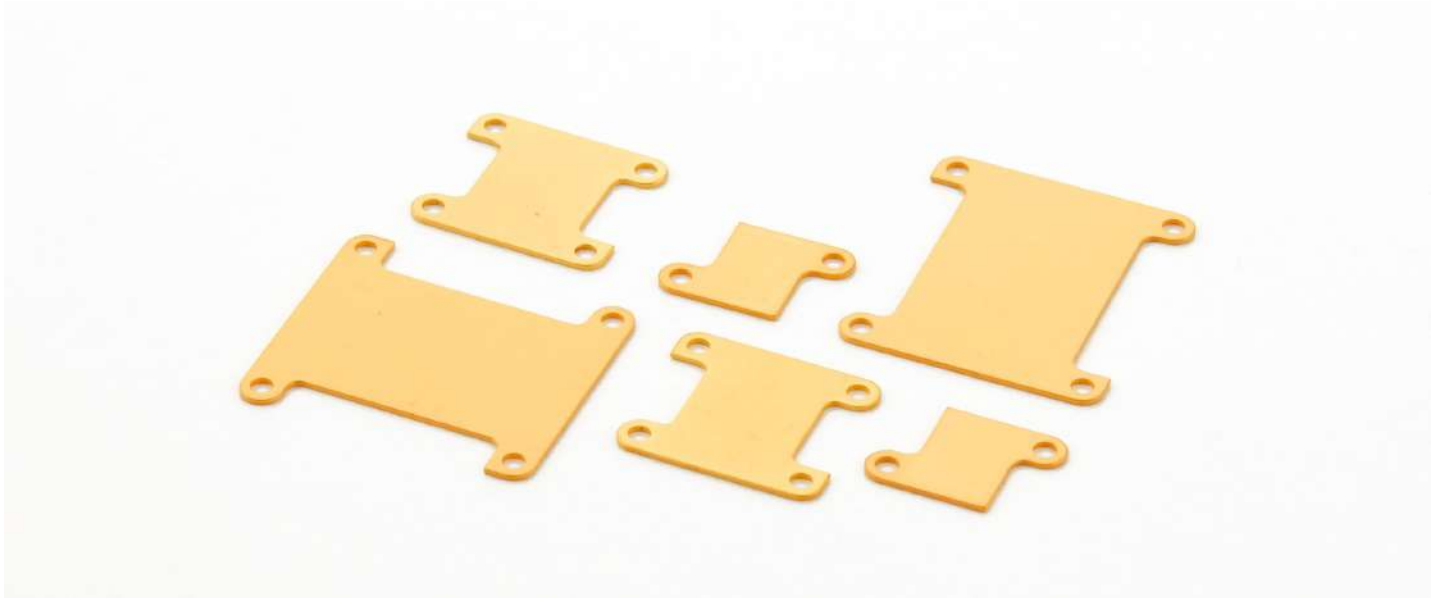
- EOS PA2200 (Unfilled Polyamide)
- EOS PA3200GF (Glass Fiber Reinforced polyamide)
- EOS Alumide (Aluminum Reinforced Polyamide)
- EOS ALM HP11-30 (Carbon Fiber Reinforced Polyamide)
- EOS PrimeCast 101 (Polystyrene)

# SOĞUKTAŞ PRODUCTS

SOĞUKTAŞ products are refractory metal based (Tungsten-Copper (W-Cu) and Molybdenum-Copper (Mo-Cu)) materials used in microelectronic packaging and thermal management applications. In these materials, low expansion properties of tungsten and molybdenum have been combined with the excellent thermal conductivity properties of copper. These parts, which can have different coatings, can be designed and manufactured according to the requirements of density, thermal conductivity and thermal expansion coefficient.

Material	$k_{  }$ (W/m-K)	CTE (ppm/K)	Yoğunluk (g/cm <sup>3</sup> )
Cu-W	180-240	6.5-10.5	15.6-17.0
Cu-Mo	150-240	7-11.5	9.5-10

CTE: Thermal Expansion Coefficient  
k: Thermal conductivity



# YELİMİD OA-1555

## HIGH TEMPERATURE RESISTANT STRUCTURAL ADHESIVE

### Product Description

YELİMİD OA-1555 is a modified reactive polyimide adhesive solution that is designed to provide exceptional high temperature service in a variety of demanding applications. YELİMİD OA-1555 has a long-term performance in service environments reaching up to 300°C, but it also shows instantaneous resistance at temperatures up to 450°C.

YELİMİD OA-1555 provides a higher flexural strength than most polyimides and also adheres well to various materials. When properly cured, YELİMİD OA-1555 is not affected by any solvents and chemicals, except for strong alkaline solutions that can decompose the surface and subsequently disrupt the polymer.

### Features

YELİMİD OA-1555 shows excellent adhesion strength in applications up to the 300°C. It provides excellent metal-to-metal bonding strength in properly prepared stainless steel, copper, aluminum and titanium alloys. The aging studies show that YELİMİD OA-1555 maintains its adhesion strength up to 75% in application times of up to 4000 hours at 250°C.



## Directions for Use

- For best performance, the surfaces to be bonded must be cleaned and degreased
- To obtain high-strength structural bonds, special surface preparation methods (sandblasting or sanding) increase the adhesion strength
- Apply the adhesive to both surfaces to obtain maximum adhesion strength
- Dry the adhesive applied parts in vacuum at 35°C or oven at 65°C for half an hour to evaporate the solvent in the adhesive. Then attach the adhesive applied surfaces together
- Cure the attached parts in oven for 1 hour at 175 ° C, 1 hour at 225°C, 2 hours at 280°C, 1 hour at 310°C, and 1 hour at 320°C

## Physical Properties

### Typical Uncured Properties

Color	Dark Brown
Viscosity, @ 25°C, Pa.s	1 - 50
Density, g/ml	1.03
Solid %	%75
Shelf Life, @ 18°C	1 year

### Typical Cured Properties

Glass Transition Temperature (Tg), (ASTM D7028), °C	360
Lap-Shear Strength, (Adhesion to Steel, ASTM D1002)	
@ 25°C	16 MPa
@ 150°C	14 MPa

# PYROTECHNIC SYSTEMS

Pyrotechnic systems offer highly reliable solutions to meet ignition, pressure and mechanical effect requirements of subsystems belonging to military munitions, space vehicles and manned/unmanned military/civil vehicles. Design, manufacture and qualification activities of pyrotechnic systems are accomplished according to military standards and customer requirements.

## INITIATORS

Initiators are used for the activation of pyrotechnic systems, rocket motor igniters and thermal batteries

All Fire Current	3.5 A 50 ms (-62°C /+107°C)
No Fire Current	1 A /1 W 5 minutes (-62°C /+107°C)
Activation Time	< 25 ms
Nominal Peak Pressure	5 - 30 bar @ 10 cc
Number of Bridgewires	1 - 2

AK 6-1



AK 9-2



AK 9-3



AK 9-4



## PRESSURE CARTRIDGES

Pressure Cartridges are used to meet pressure requirements of munition subsystems.



BK 375U-1



BK 500U-1

All Fire Current	3.5 A 50 ms (-62°C /+107°C)
No Fire Current	1 A /1 W 5 minutes (-62°C /+107°C)
Activation Time	< 20 ms
Nominal Peak Pressure	10 - 400 bar @ 10 cc
Number of Bridgewires	1

## GAS GENERATORS

Gas Generators are used to meet high pressure requirements of munition subsystems (e.g. releasing wings in wing actuation systems).



GJ 1



GJ 2

Activation Time	< 1 s
Nominal Peak Pressure	10 - 300 bar @ 100 cc

## PIN PULLERS

Pin Pullers are used to release side forces applied on pin surface (e.g. releasing munition subsystems).

Activation Time	< 50 ms
Pin Length	15 - 35 mm
Stroke	< 5 mm
Side Force	100 - 2000 N (Survive) 100 - 1000 N (Operating)



PC 150-1



PC 650-1



PC 650-2



PC 650-3



PC 650-4

## PIN PUSHERS

Pin Pushers are used for fracture, rupture, push components of munition subsystems (e.g. opening of air line of cooling gas tank).



PI 250-1



PI 250-2

Activation Time	< 50 ms
Stroke	1 - 10 mm
Initial Impact Force	> 1000 N
Final Impact Force	> 100 N

## CABLE CUTTERS

Cable Cutters are used to cut cables/wires in munitions (e.g. opening of air vent).



KK 6-1



KK 7-1

Activation Time	< 50 ms
Functional Performance	cut 5 mm OD copper and cut 3 mm OD AISI 316 wire rope (DIN 3060 7X19)

## PYROTECHNIC VALVE

Pyrotechnic Valves are used to open/close liquid and gas lines in munitions.



PV K1

Activation Time	< 10 ms
Proof Pressure	10 bar
Operating Pressure	4 bar
Flow Rate	< 0.20 kg/s
Pressure Drop	< 4 kPa

## PYROTECHNIC BOLTS

Pyrotechnic Bolts are used to provide separation of munition subsystems (e.g. releasing of engine cover).



CV N1



CV F1

Activation Time	< 50 ms
Tensile Load	2000 N - 45000 N (Operating)
Functional Performance	Separation into two pieces without creating any debris (non-fragmenting) or fragmentation around desired break area (fragmenting)

## ROCKET MOTOR IGNITER

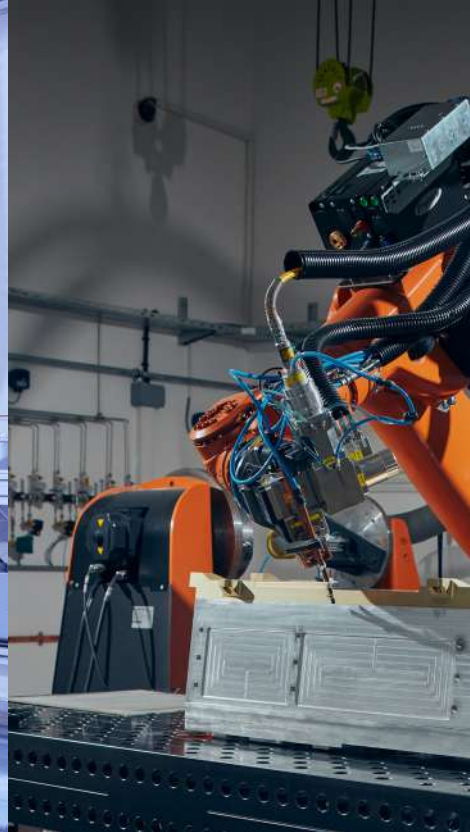
Rocket Motor Igniters are used for the ignition of solid propellant rocket motor.

Activation Time	< 20 ms
Functional Performance	Ignites HTPB - AP solid fuel rocket motor



RMA 1







# INFRASTRUCTURES AND CAPABILITIES

# ANKARA WIND TUNNEL

Many experiments can be carried out in wind tunnels when investigating aerodynamic properties of air vehicles such as aircraft, helicopters, parachutes, UAVs, and ground vehicles such as cars, trucks, buses and motorcycles, finding the effect of air flow on buildings and bridges, determination of interactions of objects such as antenna, siren, lightning rod with air and examination of their strength in stormy environment. For this purpose, Ankara Wind Tunnel (AWT) was built between 1946-1950 and has been modernised, regularly maintained and repaired by TÜBİTAK-SAGE since 1993. AWT is horizontal closed loop, atmospheric with tunnel with closed test section, operating at low subsonic speeds. It is the first wind tunnel in Turkey and there was no similar property in the Balkans including the period in which AWT was constructed. The test section has a width of 3.05 m, a height of 2.44 m and a length of 6.10 m. The tunnel loop is reinforced concrete and the test section is wooden. Test speed can be over 80 m/s (288 km/h) with empty test section. The axial turbulence level of the tunnel is 0.15% and the total turbulence level is 0.62%.

The actual model or scaled model to be tested is mounted to the test room where the experiment is performed, wind is given at the desired speed, the model is brought to the desired angle and the aerodynamic forces acting on the model are measured using external or internal balance systems. Nowadays AWT has been actively used by universities, civil sector firms and defense industry companies. Organization named Subsonic Aerodynamic Testing Association (SATA) in 2000, which was established to discuss the issues related to the design, operation, maintenance, and physical measurement and instrumentation of low speed wind tunnels. A large number of tests have been carried out in AWT with different categories especially in aviation, automotive, environmental testing and civil requirements.

Capabilities





- External balance system
- Internal balance systems (3 balances with different sizes & limits)
- Model Support System (MSS) integrated with external balance system and compatible with sting type internal balances.
- Pressure Sensitive Paint System
- Constant Temperature Anemometer (CTA)
- Surface Pressure Measurement
- Structural Strength Tests
- Tuft, Smoke and Oil Flow Visualization Tests

It is possible to measure force accurately in the angle of attack range of  $-20^{\circ}$  to  $+50^{\circ}$  and in the yaw angle range of  $-30^{\circ}$  to  $+30^{\circ}$  utilizing model support system with a high positioning accuracy of  $0.025^{\circ}$ . AWT is the only wind tunnel having pressure sensitive paint system in Turkey and it becomes possible to perform pressure measurement without disturbing the flow by eliminating the problems arising in traditional methods. In addition, 3 pieces of 3-axis hot wire probe in the CTA can be used to precisely measure turbulence level in the tunnel.



## NON-DESTRUCTIVE QUALITY CONTROL LABORATORY

Non-destructive quality control laboratory which was constructed at 2004, is a part of quality control division. Laboratory personnel are certificated according to EN ISO 9712. Radiographic inspection, ultrasonic inspection, magnetic particle testing, liquid penetrant testing and visual inspection systems available in non-destructive quality control laboratory, are described below.

## **Radiographic Inspection Capabilities:**

### **X-Ray System (Y. Access 100 X-Ray System):**

Y. Access 100 X-Ray has 450 kV mini focus tube and 14 bit flat panel detector. The system is capable of moving in 4.5x9 m<sup>2</sup> space. The workbench was specially designed to meet all testing requirements. Samples have length of 8000 mm and diameter of 1000 mm can be inspected by using this X-Ray system and the workbench.

### **X-Ray Tomography System (Y.CT Modular X-Ray System):**

Y.CT Modular X-Ray System is used for 2-dimensional and 3-dimensional X-Ray inspection (computed tomography) has 450 kV mini focus tube, 225 kV micro focus tube and 16 bit flat panel detector. Samples have length of 500 mm, diameter of 320 mm and weight of 50 kg can be inspected by using CT Modular system. The penetration depth of X-Ray beam in a bulk steel is about 65 mm. Failure analysis, thickness analysis, geometric measurements and nominal/actual comparison is possible on 3-dimensionally inspected parts.

## **X-Ray Systems for Electronics**

### **Y. Cougar SMT X-Ray System:**

Y.Cougar X-Ray System has 160 kV multi focus tube and 14 bit flat panel detector. It is used for 2-dimensional X-Ray inspection of printed circuit boards (PCB's) and electronic assemblies.

### **Y. Cheetah SMT X-Ray System:**

Y.Cheetah X-Ray System has 160 kV multi focus tube and 16 bit flat panel detector. It is used to inspect printed circuit boards (PCB's) and electronic assemblies. Apart from the other X-Ray system, computed laminography and computed tomography options are available.

### **Portable X-Ray System (Vidisco-Flatfox):**

Vidisco-Flatfox X-Ray system is mobile and it is used for digital radiographic inspection. It both operates with internal 270 kV X-Ray tube and an external 300 kV mini focus tube. Portable X-Ray system is used outside of the institute for outdoor X-Ray inspection.

## **Magnetic Particle Testing Capabilities:**

Magnetic particle testing is used for the detection of surface/subsurface imperfections in ferromagnetic materials. Test can be performed under UV or visible light.

For magnetic particle inspection, AC&DC hand yoke (AC 230V, 50Hz) and MP 2500 AC\_FWDC Magnetic Particle Testing System are available in non-destructive testing quality control laboratory. Ferromagnetic samples have length of 2500 mm and diameter of 500 mm can be inspected by using MP 2500 AC\_FWDC Magnetic Particle Testing System and surface/subsurface imperfections can be detected.

### Ultrasonic Test Capabilities:

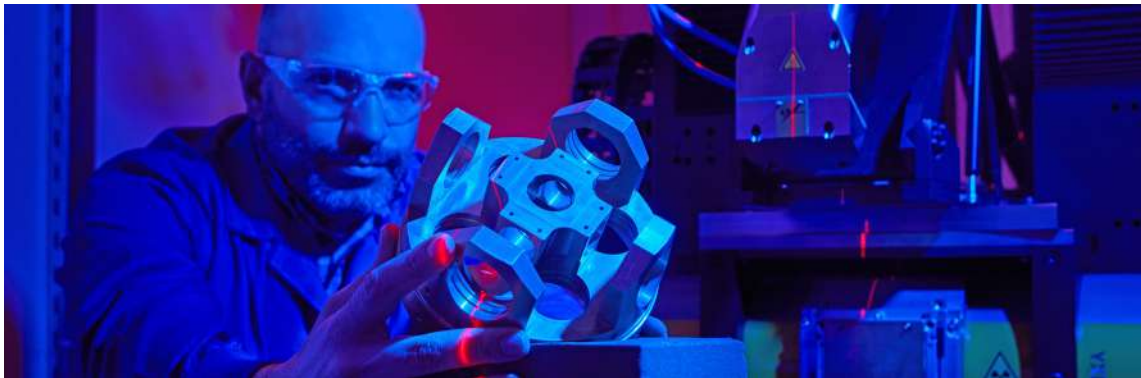
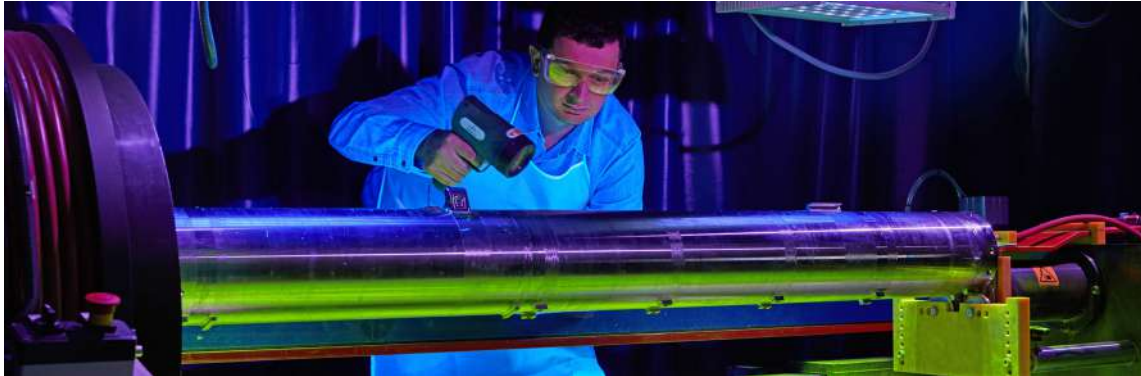
Ultrasonic inspection is a bulk inspection technique which is preferred for the detection of internal imperfections that cannot be observed with radiography. Two conventional ultrasonic test equipment, (EPOCH 4PLUS, GE USM GO) and one phased array ultrasonic test equipment (Olympus OmniScan MX2) are available in non-destructive testing quality control laboratory.

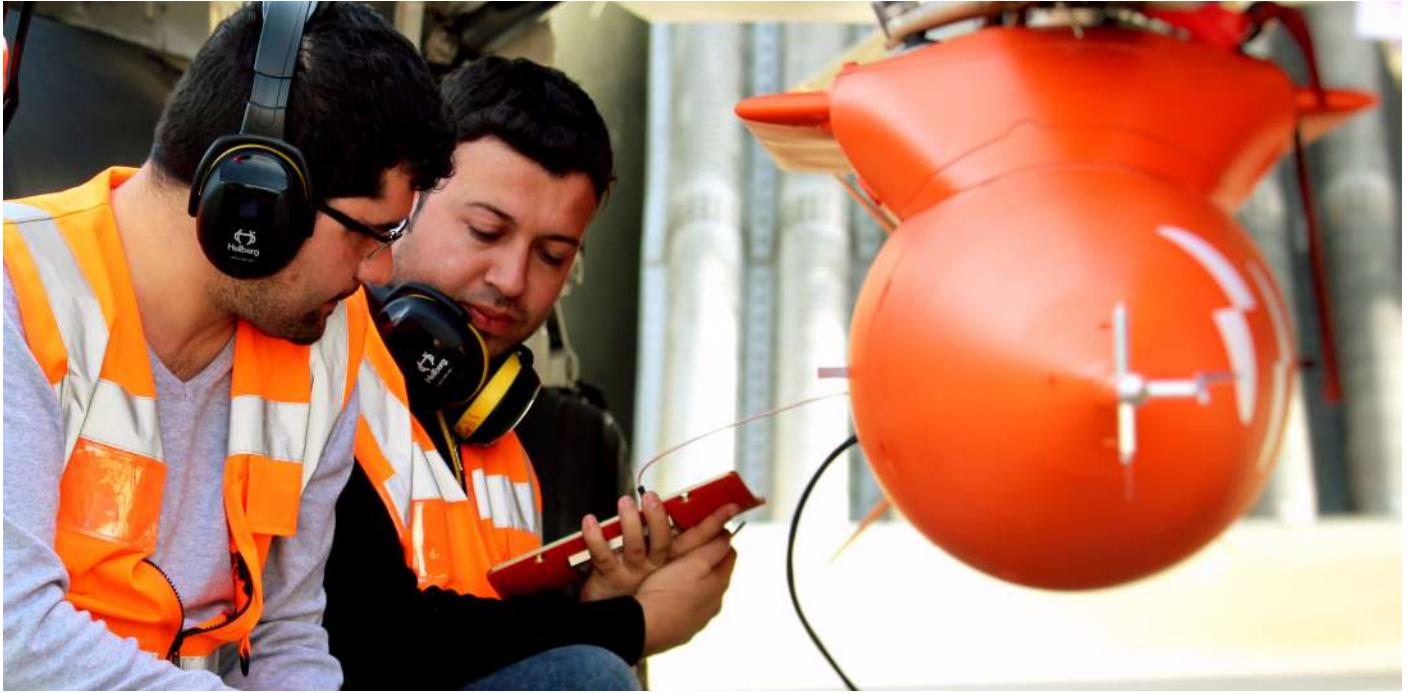
### Liquid Penetrant Testing Capabilities:

Discontinuities open to the surface of a material can be detected by liquid penetrant testing. The material surface should be clean and uncoated to allow the penetration of liquid dye into the discontinuities. Test can be performed under UV or visible light.

### Visual Inspection Capabilities:

Surface discontinuities are inspected by qualified personnel using visual inspection techniques. These techniques includes use of some lighting and measurement tools like torch, callipers, magnifying glass etc. For the visual inspection of non-reachable parts of the specimens, Videoscope Instrument has a fiber-optic cable with 6 mm diameter and 2 m length (GE Mentor Visual IQ VideoProbe) is used.





# MUNITION TEST EQUIPMENT INSTALLATION INFRASTRUCTURE

## Infrastructure Responsibilities:

Main mission of the facility is the installation of test equipment and sensors within the munition which are designed and tested for the platform integration purposes.

## Primary Capabilities:

- Data acquisition from munition and platform by using proper pressure, temperature, vibration, acoustic etc. Sensors, during integrated ground tests, captive flight test, jettison, release and firing tests
- Design and application of integration of telemetry equipment to the munition
- Installation design and equipment selection to be implemented on test aircraft for data acquisition of MUX-BUS data
- Installation Design and integration of “Flight Termination Systems” onto the munition

# HABRAS

## WARHEAD HIGH SPEED ROCKET TEST TRACK

Warhead High Speed Rocket Test Track called HABRAS is one of the ground test facilities that is built and operated by TÜBİTAK SAGE to provide dynamic testing services for defense and aerospace researches. HABRAS is one of the few high speed test tracks in the world with 2-km long double rail system. It is located at the Turkish MoD Firing Range, Test, and Evaluation Centre in Karapınar/Konya.

HABRAS is a kind of ground-based test facility that means it can offer a cost-effective, realistic/tactical, and controlled dynamic test environment for high speed systems and subsystems as warheads and aerospace components. HABRAS is capable to speed the payload more than 1 tons up to Mach 1.5. HABRAS can provide dynamic test environments for various systems/subsystems, the some are listed below:

- **Munition Systems:** Warheads (penetrator, shaped charged and etc.), fuzing systems, propulsion systems, seeker and guidance systems
- **Rescue Systems:** Ejection seats, parachutes, canopy jettison systems and rescue kits
- **Environmental Effects:** Rain/ice/particle erosion, high G-loads and blast
- **Propulsion Systems:** Solid/liquid propellant rocket motors, aircraft/space shuttle engine tests



# TELEMETRY INFRASTRUCTURE

TÜBİTAK SAGE has been using telemetry systems since 2005. As mobilized in 2007, these systems are providing service to not only TÜBİTAK SAGE but also all defense industry according to their needs and requirements within a constant improvement process.

## Facility Capabilities

Telemetry Infrastructure is used as acquiring data from instrumented test subjects and from instrumented test aircrafts during captive carry flight tests, jettison test and release/firing tests.

There are 2 independent mobile telemetry systems in this facility.

- Mobile Telemetry System
- GÖZCÜ Telemetry System

## Telemetry Capacity

- RF data receiving at 23Mb/s rate
- RF and GPS auto tracking antennas
- 250+ km range
- 2D and 3D data monitoring
- Geographical applications
- Redundant tracking of a single target with 2 antennas and 2 target tracking abilities
- IF band recoding
- Data synchronization with IRIG-B time
- Flight termination system





## KRİTEK

### CRITICAL COMPONENT TECHNOLOGY RESEARCH AND DEVELOPMENT INFRASTRUCTURE

Critical Component Technology Research and Development Infrastructure (KRİTEK) was established in 2003 regarding the purpose of conducting R&D activities and prototype production of the materials and technologies with national capabilities which are critical in the defense, space and aerospace industries. After reaching considerable success in the development of the penetrating fragments and rotating band sub-components of the 35 mm Fragmented Projectile as the first output of the R&D activities, KRİTEK Infrastructure have initiated to support all the projects conducted in the TÜBİTAK SAGE at the system and sub-system level. In particular, indigenous development of materials, components and special production processes, which are classified as critical and cannot be acquired from abroad, has been determined as the main goal and many national and indigenous products have been developed since then within the scope of this target.

The infrastructure, which has been constantly evolving in terms of its device capabilities since the day it was established, can respond immediately to all demands coming in and out of TÜBİTAK SAGE with its unique facilities.



KRİTEK, with its interdisciplinary researcher power, expert technician and wide range of device facilities, creates unique environment for development of critical materials, sub-components, special process and technology. Within this context, many interdisciplinary R&D and production activities are performed in the infrastructure, including the main studies listed as;

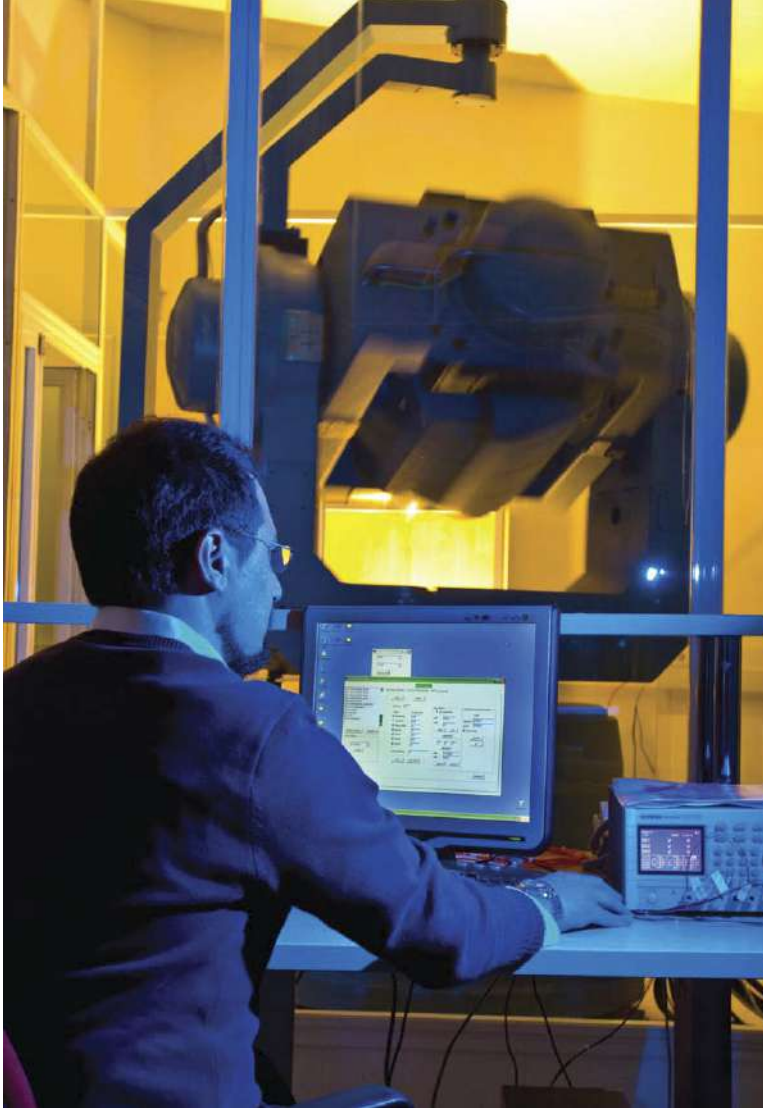
- Advanced metal alloys and ceramic materials,
- RF substrate and antenna technologies,
- Sensor technologies,
- Critical optical materials,
- Warhead penetrating performance technologies,
- Insensitive munition technologies,
- Reactive materials technologies,
- Thermoelectric and thermal management materials technologies,
- Thin film coating technologies,
- Microtechnology products,
- Electromagnetic propulsion systems.



Furthermore, production and forming of various materials through powder metallurgy, vacuum metallurgy and thermomechanical techniques are conducted. Correspondingly, mechanical, chemical and physical testing and characterization of materials are performed in the infrastructure. The laboratories in the KRİTEK are given below:

- Heat Treatment Laboratories
- Thermomechanical Processing Laboratories
- Mechanical Production Laboratory
- Ceramics Laboratory
- Metallography Laboratory
- Powder Metallurgy Laboratory
- Coating Technologies Laboratory
- Antenna Technologies Laboratory
- Sensor Technologies Laboratory
- Electromagnetic Laboratory
- Mechanical and Physical Testing Laboratory
- Characterization Laboratories





# INERTIAL SENSOR LABORATORY

Inertial Sensor Laboratory is the oldest infrastructure of TÜBİTAK SAGE, located in the campus of Middle East Technical University.

Inertial measurement Unit (IMU) provides necessary outputs for autopilot and navigation process by measuring linear acceleration and angular rates of the vehicle. IMU mainly contains inertial sensors (three rate gyros and three accelerometers for three axes), IMU processing electronics, mechanical assembly and processing software.

## CAPABILITIES

Inertial Sensor Laboratory serves to provide testing and calibration of Inertial Navigation System (INS), IMU, accelerometer and gyroscope used for navigation and guidance systems.

Inertial Sensor Laboratory serves to provide testing and calibration of INS, IMU, accelerometer and gyroscope used for navigation and guidance systems.

## ALLAN VARIANCE TESTS

Data should be taken for long time (for hours) without giving input to the IMU. Allan variance is the average of the variance of adjacent pairs of elements in a contiguous time series of data versus the averaging time used to generate the elements. Allan variance results are related to basic sensor noise terms given below:

***quantization noise, angle random walk, bias instability, rate random walk, rate ramp.***

## CALIBRATION TESTS

Error models of inertial sensors used in IMU are calculated with calibration tests. Each IMU is calibrated separately. Calibration tests can be performed by using two axis position/rate table or three axis motion simulator. Highly sensitive rate and acceleration inputs can be given to the IMUs using these equipments. As a result of position tests, bias, scale factor and misalignments of accelerometer and bias of gyroscopes are calculated.

Gyroscope and accelerometer calibration matrix are constituted with these calculated parameters and this matrix can be used during navigation process and IMU software.

Calibration tests can be repeated to find the temperature dependence of the calibration parameters.

## FACILITY CAPABILITIES

- Index table
- 3-Axis Motion Simulator
- Centrifuge
- 2-Axis Motion Simulator





## ENVIRONMENTAL TEST LABORATORY

Environmental Tests are carried out to determine the resistance of sub-systems and systems to the natural environmental conditions, which they may face through during their life cycles.

TÜBİTAK SAGE Environmental Test Laboratory is accredited by Turkish Accreditation Agency (TÜRKAK) according to TS EN ISO/IEC 17025 standard with respect to after mentioned tests.



## TEMPERATURE SHOCK TEST

Temperature Shock Test is used to determine if test sample can withstand sudden changes in the temperature of the surrounding atmosphere without experiencing physical damage or deterioration in performance. After installation of the test sample into the test chamber, the temperature shock conditions is applied to the test sample by considering the real temperature shock conditions that the test sample will be exposed. Physical inspection and operational checkout of the test sample are performed during and/or after the test and any failure is recorded.

## LOW PRESSURE (ALTITUDE) TEST

Low Pressure (Altitude) Test is used to determine if materiel can withstand and/or operate in a low pressure environment and/or withstand rapid pressure changes. After installation of the test sample into the test chamber, it is exposed to low pressure by considering the real pressure conditions that the test sample will be exposed. Physical inspection and operational checkout of the test sample are performed during and/or after the test and any failure is recorded.

## SALT FOG TEST

Salt Fog Test is used to determine the effectiveness of protective coatings and finishes on test samples and salt deposits on the physical and electrical aspects of test sample. After installation of the test sample into the test chamber, it is exposed to salt fog atmosphere. The physical, electrical checkout and the corrosion examination of the test sample are conducted after the test and any failure is recorded.



## RAIN TEST

Rain Test is used to determine the following with respect to rain, water spray, or dripping water:

- The effectiveness of protective covers, cases, and seals in preventing the penetration of water into the materiel
- The capability of the materiel to satisfy its performance requirements during and after exposure to water
- Any physical deterioration of the materiel caused by the rain
- The effectiveness of any water removal system
- The effectiveness of protection offered to a packaged materiel

After installation of the test sample into the test chamber, it is exposed to rainfall conditions by considering the real rainfall conditions that the test sample will be exposed. Physical inspection and operational checkout of the test sample are performed during and/or after the test and any failure is recorded.

## HUMIDITY TEST

Humidity Test is used to determine the resistance of the test sample to the effects of a warm, humid atmosphere. After installation of the test sample into the test chamber, it is exposed to humid environment, which is appropriate to the usage and storage conditions of the sample, for an appropriate time interval. Physical inspection and operational checkout of the test sample are performed during and/or after the test and any failure is recorded.

## VIBRATION AND SHOCK TESTS

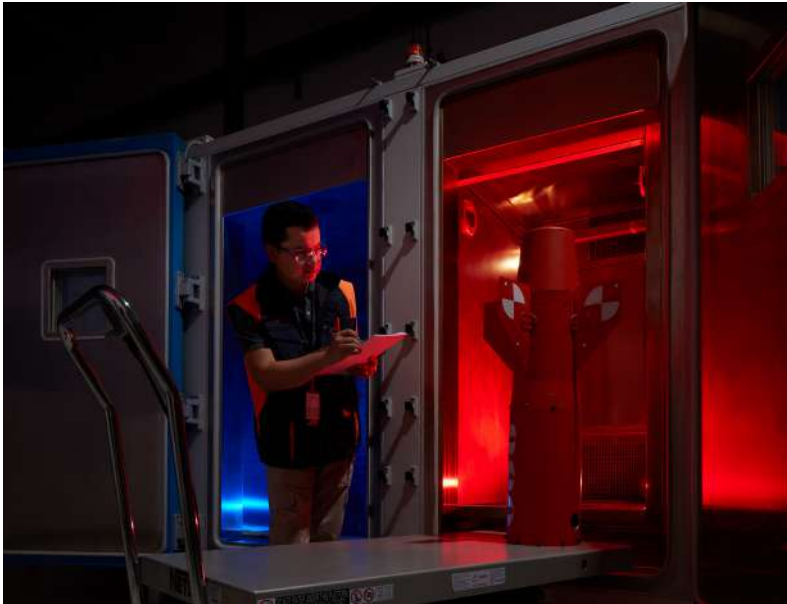
Vibration and Shock Tests are used to determine effects of dynamic forces on the test sample safety, integrity and performance. The acceptability limits are determined by using civil/military standards or data acquisition under the most real operation environment. The dynamic forces are simulated in laboratory environment by using data acquisition systems, control systems, sensors, shakers and portable climatic chamber if needed. Physical inspection and operational checkout of the test sample are performed during and/or after the test and any failure is recorded.

## HIGH TEMPERATURE TEST

High Temperature Test is used to determine effects of high temperature conditions on the test sample safety, integrity, and performance. After installation of the test sample into the test chamber, it is exposed to high temperature environment, which is appropriate to the usage and storage conditions of the sample, for an appropriate time interval. Physical inspection and operational checkout of the test sample are performed during and/or after the test and any failure is recorded.

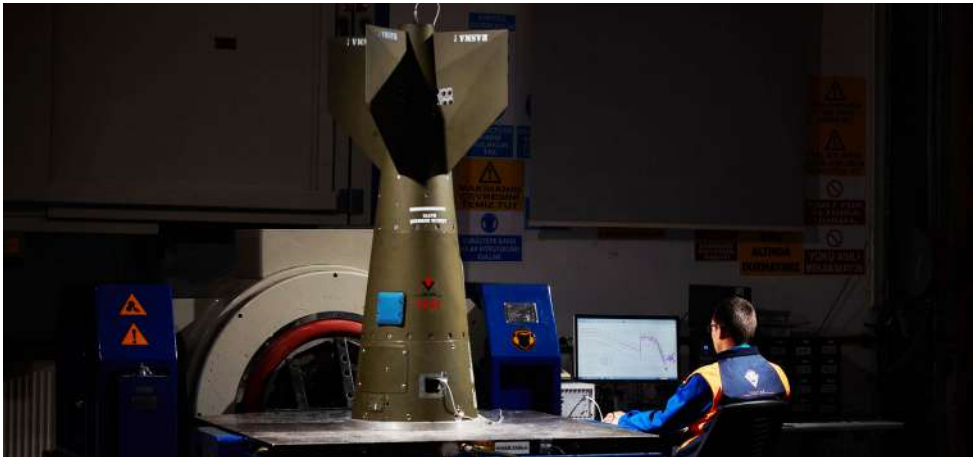
## LOW TEMPERATURE TEST

Low Temperature Test is used to determine effects of low temperature conditions on the test sample safety, integrity, and performance. After installation of the test sample into the test chamber, it is exposed to low temperature environment, which is appropriate to the usage and storage conditions of the sample, for an appropriate time interval. Physical inspection and operational checkout of the test sample are performed during and/or after the test and any failure is recorded.



## ACCELERATION TEST

Acceleration Test is used to assure that test sample can structurally withstand the steady state inertia loads that are induced by platform acceleration, deceleration, and maneuver in the service environment, and function without degradation during and following exposure to these forces. After installation of the test sample onto the test device, it is exposed to acceleration environment, which is appropriate to the usage and storage conditions of the sample, for an appropriate time interval. Physical inspection and operational checkout of the test sample are performed during and/or after the test and any failure is recorded.



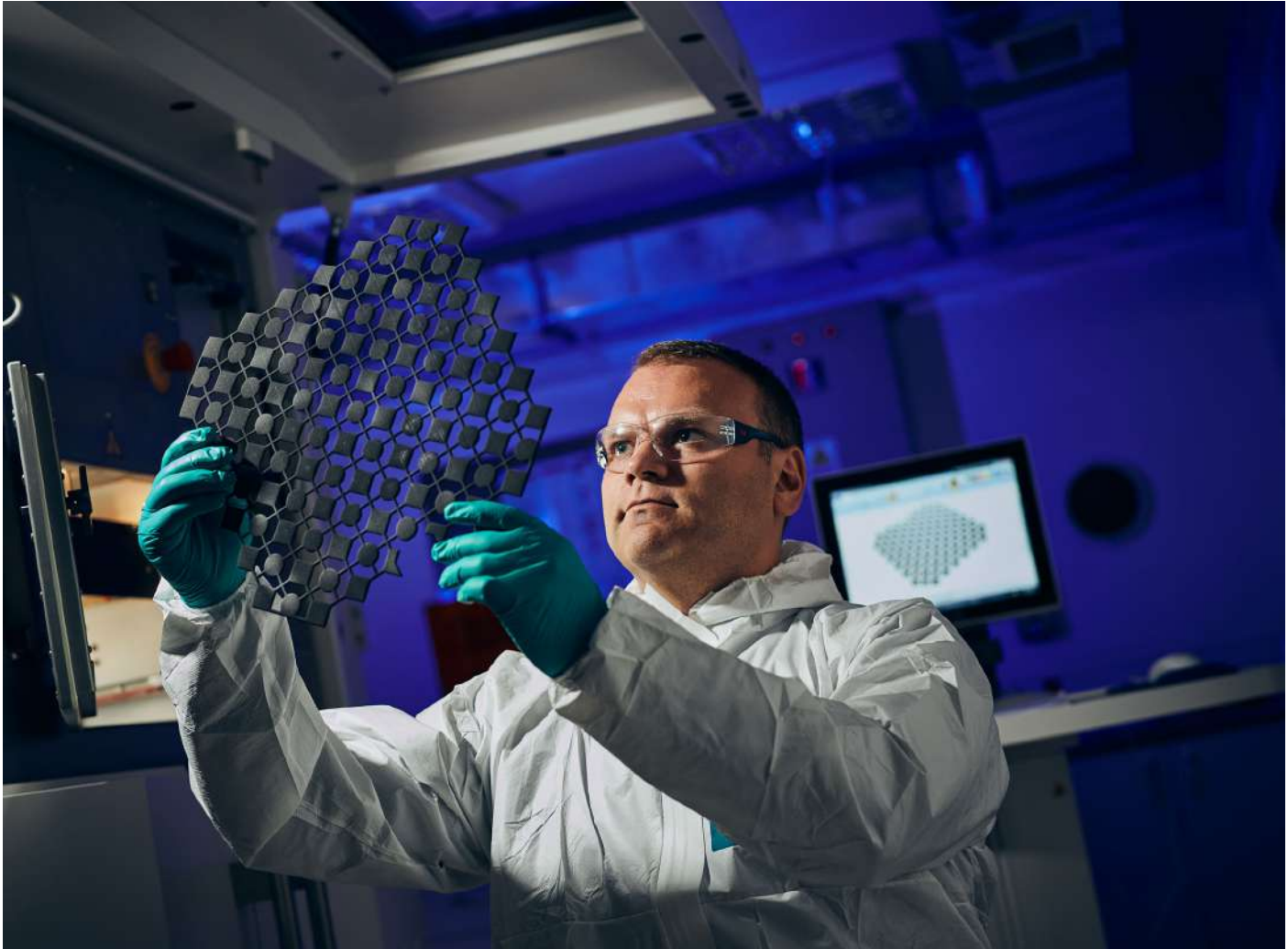


# CHEMICAL QUALITY CONTROL LABORATORY

Chemical quality control laboratory fulfill the quality control and characterization needs of TÜBİTAK SAGE by testing and analysing various types of materials such as propellants, explosives, pyrotechniques, insulation materials, composites and different types of polymers.

Thus, chemical quality laboratory has the ability to perform different type of tests/analyses including thermal analysis with DSC, TGA, TG-DTA and DMA; friction and impact sensitivity tests, burning rate analysis, oxygen bomb calorimeter tests of energetic materials; FTIR and HPLC analysis, apparent density, shore A hardness and viscosity measurements. In addition to instrumental analyses, chemical quality laboratory also performs analytical tests such as lithium content, iron content, hydroxyl value, purity and insoluble material content test/analyses.

- Dynamic Mechanical Analysis (DMA)
- High Performance Liquid Chromatography (HPLC)
- Diferential Scanning Calorimetry (DSC)
- Termogravimetric Analysis (TGA)
- Termogravimetric- Diferential Thermal Analysis (TG-DTA)
- Fourier-Transform Infrared Spectroscopy
- Oxygen bomb calorimeter
- Impact Sensitivity Test Apparatus
- Friction Sensitivity Test Apparatus
- Apparent Density / Helium Pycnometer
- Karl Fischer Titrators (Volumetric and Coulometric Types)
- Thermal Conductivity Analyzer



## **GENERAL CHEMISTRY AND POLYMER ADDITIVE MANUFACTURING TECHNOLOGIES FACILITY**

Facility has a general chemistry laboratory in addition to its additive manufacturing capabilities. Works involving synthesis and characterization of polymeric materials are mainly conducted in this laboratory. Some technical capabilities of the facility can be listed as following:

## Selective Laser Sintering Device (SLS 3D Printer)

Production Volume : (x:y:z) 340 mm:340 mm:600 mm  
Laser Source : 70W CO<sub>2</sub> laser  
Production Speed : 32 mm/h  
Layer thickness : 120 μm

## Printable Materials

- EOS PA2200 (Unfilled Polyamide 12)
- EOS PA3200GF (Glass-fiber reinforced Polyamide 12)
- EOS Alumide (Aluminum filled Polyamide 12)
- EOS ALM HP11-30 (Carbon-fiber reinforced Polyamide 11)
- EOS PrimeCast 101 (Polystyrene)



## Dynamic Mechanical Analysis (DMA)

Dynamic Mechanical Analysis (DMA) device can exert forces up to 450N with a frequency range of 1-200Hz and a temperature range between -150°C to +450°C.



## FTIR Spectrometer

Transportable FTIR device can scan the spectrum in-between 8000 - 350 cm<sup>-1</sup>. Device can be operated in Transmittance, Reflectance and ATR modes. Heating of the sample is possible for transmittance mode.



## DSC-TGA

System measures the thermal responses of the material in-between room temperature to 1000°C. Differential Scanning Calorimeter (DSC) and Thermal Gravimetric Analysis (TGA) data can be obtained simultaneously.



## TERMINAL BALLISTICS FACILITY

Terminal Ballistics Facility is a facility where the terminal ballistics related tests are conducted.

Capabilities of Terminal Ballistics Facility are

- Tests conducted on Light Gas Gun System
- Tests conducted on 100 mm Gun Barrel System
- Tests conducted on 12 and 25 mm Caliber Powder Gun System
- Tests conducted on Flash X-Ray System

## LIGHT GAS GUN SYSTEM

Light Gas Gun System is a system which fragments and bullets are accelerated to desired high speed impact velocities in laboratory conditions.

## 100mm GUN BARREL SYSTEM

100mm Gun Barrel System accelerates test samples using gunpowder to desired high impact velocities.

Using this system,

- Penetration capability tests of high velocity projectiles,
- Penetration capability tests of scaled model of the munitions
- Tests regarding the examination of material characteristics at high strain rates can be conducted.

## 12mm & 25mm CALIBER POWDER GUN

This system contains 12mm and 25mm caliber barrels. Test fragments are accelerated via powder. Powder gun is protected with steel powder gun shelter.

## FLASH X-RAY SYSTEM

Flash X-Ray system is used for imaging very rapid ballistic applications (elapsing in microseconds) such as high speed impact, fragmentation and explosion. Unlike other systems like high speed cameras, this system is capable of imaging in dusty, smoky and flammable ballistic test environment.





## ADVANCED MANUFACTURING TECHNOLOGIES INFRASTRUCTURE

Advanced Manufacturing Technologies Infrastructure performs research and development activities on laser material processing for the aerospace, defense and space industries in the following areas:



- Laser joining (laser welding, laser-hybrid, laser-soldering etc.)
- Laser surface treatment
- Laser cutting/drilling
- Laser material deposition
- Laser powder bed fusion
- Vacuum brazing
- Orbital welding
- Pressure vessel manufacturing and qualification
- Rapid production
- Welding and heat treatment modelling and simulation
- Robot programming and offline simulation

### Equipments

- 10 kW Yb Fiber Laser
- 10 Axes Robotic Laser Kaynak System
- 450 W/4500 W Multi-Axis Laser Welding Workcell
- 400 W x 2 Laser Powder Bed System (500 x 280 x 350 mm ) (L x W x H)
- 400 W Laser Powder Bed System (280 x 280 x 350 mm ) (L x W x H)
- 10 kW Laser Welding Head
- 10 kW Laser Wobble Welding Head
- Gravimetric Powder Feeding System
- 100 W CO2 Laser Cutting System
- Twin Spot Module
- Laser Path Finder
- Hot/Cold Wire Feeder
- Two and One-axis Positioner
- Slider System
- Orbital Tungsten Inert Gas Welding System
- 1250 °C Vacuum Heat Treatment Furnace
- 1000 bar Hidrostatic and Fatigue Testing System
- 650 bar Pneumatic Testing System
- Different Welding Gases ( Ar, He, Ar-He, etc.)
- Welding and Heat treatment Modelling and Simulation Software
- Robot Programming and Offline Simulation Software



## COMPOSITE TECHNOLOGIES DEVELOPMENT AND PRODUCTION INFRASTRUCTURE

In the Composite Technologies Development and Production Infrastructure, vacuum infusion, VARTM and hot press methods are used in the production as well as research and development of composite materials. The production of many composite materials which are critical in defense, aerospace and aerospace industries such as carbon or glass fiber reinforced epoxy, phenolic, polyimide, benzoxazine, cyanate ester and silicon are realized within the scope of infrastructure activities.

Silica phenolic composite products for solid-propellant missiles, radomes used in ammunition, antenna radomes, warheads, protective caps are among the products developed by the infrastructure. In addition, application of adhesives and encapsulation of electronic components are carried out for projects within the scope of infrastructure activities. Tests for life determination and armor effectiveness of materials are among the activities carried out. Products developed by the Composite Technologies Development and Production Infrastructure and the devices within the infrastructure are given below.

### **Devices**

Used in Armor effectiveness analysis. Mechanical strength analysis of metal alloys, ceramic and polymer materials at very high tensile and compression rates (strain rates between 100/s to 10000/s) can be done by this device.

### **Automated Ply-Cutting Machine**

Used for dry fabric and prepreg cutting for composite production.

### **Composite Curing Oven**

Heating capacity in the temperature range of 50°C-200°C

### **Hot Press**

- Heating capacity in 50°C-350°C temperature range
- Pressing capacity up to 30.000 kg load

### **Press**

Pressing capacity up to 9.000 kg load

### **Climatic Test Cabinet**

- Temperature control in the range of -40°C/ + 150°C
- Humidity control in the range of 15% - 98%

### **Vacuum Assisted Resin Transfer Molding**

Heating capacity in 50°C-260°C temperature range

### **Developed Products**

- Silica Phenolic Composite Products
- Carbon Fiber Reinforced Phenolic Composite Products
- Silica Fiber Reinforces Silicone Composite Products
- Glass Fiber / Epoxy Composite Products
- High Temperature Resistant Composite Radomes





## OPTOMECHATRONIC LABORATORY INFRASTRUCTURE

Optomechatronic Laboratory is responsible of provide required facilities for assembly, control system development, optical measurement and calculation, test and verification of infrared and laser with or without gimbal seeker. Laboratory has the following facilities:

- Hardware in the Loop Test System
- Class 1000 Clean Room
- Optomechatronics Laboratory

## Hardware in the Loop Test System

The Hardware in The Loop Test System performs performance test of the developed seeker and its algorithm under real operational conditions. System consists of these subsystems:

- 5 axes Flight Simulator
- Infrared Scene Generator
- Infrared Scene Projector

Seeker Test Centre possesses a Five-Axis Flight Motion Simulator (FMS), Infrared Sensor Scene Generator (IRSSG), and Infrared Scene Projector (IRSP) so as to simulate planned munition-target engagement scenarios built for munition having an infrared seeker. Though, the center can even be adapted to munitions with RF seekers with appropriate design modifications.

## Class 1000 Clean Room

A clean room with a cleanness level of 1000 was built in order to make the precise mounting and tests of optical and optomechanical components of the seekers. In order to that there is a small chamber which can provide class 100 cleaning level for the high sensitive process. The clean room has devices and equipment to accomplished the actions stated above as listed below:

- Infrared Test Systems
- Profilometer
- FTIR Spectrometer

## Optomechatronic Laboratory

Mechanical assembly, wiring, and other division study were performed under this laboratory. The names of the devices and systems in this section as follows:

- Gimbal Balance Instruments Device
- Portable CMM
- Pure Air Generator and Gas Tank Filling Line





## MUNITION GROUND TESTS FACILITY

### WARHEAD ARENA TEST

The purpose of this test is to evaluate and to verify the capabilities of warheads on ambient, low temperature and high temperature conditions.

### ROCKET ENGINE STATIC FIRING TEST

Rocket engine is placed upon the test fixture before it is fired. Physical datas (pressure, temperature, thrust etc.), which belong to the moment of firing, are collected by the sensors mounted on the rocket engine. The firing performance is evaluated by means of these datas recorded by data acquisition system.



## INSENSITIVE MUNITION (IM) TESTS

During its lifecycle (storage, handling, transportation, etc.), a munition may encounter different types of unplanned stimuli (hazards) that can cause an energetic response. That's why insensitive munition tests are necessary to assess possible energetic responses those would be occurred. Munition Ground Tests Facility performs insensitive munition tests those are given below:

- Liquid Fuel Fire Test
- Bullet Impact Test
- Sympathetic Reaction Test
- Slow Heating Test

## DROP TESTS

The aim of drop tests is to simulate the possible drop scenarios of test samples under certain circumstances. The resistance of test sample to drop impacts is determined.

## HYDROSTATIC TEST

The strength of rocket engines and warheads are tested by applying a certain level of pressure for a certain time. Pressure can be applied between 0 bar and 400 bar.

## STATIC EJECTION TEST (HYS 110)

The purpose of static ejection tests is to determine the reactive force loads, separation characteristics (accelerations, angular velocities, etc.) of stores released from aircraft. These tests are conducted with reference to MIL-HDBK-1763.

## LEAKAGE TEST

This test is mostly applied on munition containers and it is performed to verify that test sample provides all leakage requirements under operational conditions.



## **SLED TEST**

The aim is to verify that munition has the desired drilling efficiency when it strikes target with the desired velocity and angle. Munition is directed to target by the thrust of rocket engines. At the end of test, dynamic drilling efficiency of munition is controlled by the data high speed cameras and Doppler Radar.

## **UNDERWATER EXPLOSION TEST**

Underwater explosives are positioned at certain depths, then they are exploded. By using appropriate sensors and data acquisition system, the effects of explosion are measured.

## **OTHER TESTS (NON-CLASSIFIED)**

Initiation tests for fuses, FLSCs (Flexible Linear Shaped Charges), and other energetic materials are conducted. Also, Munition Ground Test Facility performs munition demolition operations.

## MEASUREMENT CAPABILITIES

Physical magnitudes (force, pressure, acceleration, etc.) are collected by using suitable data acquisition devices.

- Force Measurement
- Pressure Measurement
  - Closed Area and Free Field Blast Pressure Measurement
  - Rocket Engine Pressure Measurement
  - Ballistic Pressure Measurement
- Acceleration Measurement
- Temperature Measurement
- Strain Measurement
- Velocity Measurement
- Accurate Coordinate Measurement
- Meteorology Measurement





## **TÜBİTAK SAGE CALIBRATION LABORATORY**

Calibration Laboratory was accredited in 2011 under TS EN ISO/IEC 17025. The services provided by the Calibration Laboratory are briefly described below.

## Calibration Services

<p><b>Calibration of Acceleration</b></p> <ul style="list-style-type: none"> <li>• Calibration of Accelerometer</li> <li>• Calibration of Shock Accelerometer</li> <li>• Calibration of Vibration Exciter</li> </ul>	<p>0,98 m/ s<sup>2</sup> ≤ g ≤98 m/ s<sup>2</sup> (10 Hz - 10 kHz)            196 m/ s<sup>2</sup> ≤ g ≤98.000 m/ s<sup>2</sup>            9,8 m/s<sup>2</sup> (160 Hz)</p>
<p><b>Calibration of Temperature</b></p> <ul style="list-style-type: none"> <li>• Thermocouple</li> <li>• Digital Thermometer</li> <li>• Platinum Resistance Thermometers</li> <li>• Liquid Glass Thermometer</li> <li>• Oven</li> <li>• Confirmation of The Performance of Temperature Chambers</li> <li>• Confirmation of The Performance of Temperature/Humidity Chambers</li> </ul>	<p>90°C / 1100 °C            -90°C / 1100°C            -90°C / 420°C            -80°C / 420°C            250°C / 1350°C            -80°C / 200°C              23°C'de 20 %rh / 95 %rh            30°C'de 95 %rh            60°C'de 95 %rh</p>
<p><b>Calibration and Verification Static Uniaxial Testing Machines</b></p> <ul style="list-style-type: none"> <li>• Tension/Compression Testing Machines</li> </ul>	<p>20 N ≤ F ≤ 100 kN (0,5 class static loadcell/ tension )            20 N ≤ F ≤ 1000 kN (0,5 class static loadcell/ compression)</p>
<p><b>Calibration of Electronic Balance</b></p> <ul style="list-style-type: none"> <li>• Analytical Balance</li> <li>• Precision Balance</li> <li>• Industrial Balance</li> </ul>	<p>1 mg ≤ m ≤ 20 kg (E2 class mass)            10 kg ≤ m ≤ 50 kg (F1 class mass)            10 kg ≤ m ≤ 100 kg (F2 class mass)            5 kg ≤ m ≤ 200 kg (M1 class mass)</p>



<p><b>Calibration of Pressure</b></p> <ul style="list-style-type: none"> <li>Gauge/ Absolute Pressure (Analog/ Dijital Manometer Pressure Calibrator, Pressure Transducer, Pressure Transmitter, Differential Pressure Gauge)</li> <li>Dynamic Pressure</li> </ul>	<p>-0,95 bar <math>\leq</math> pr <math>\leq</math> -0,10 bar  0,7 bar <math>\leq</math> pr <math>\leq</math> 35 bar  35 bar &lt; pr <math>\leq</math> 140 bar  1 bar <math>\leq</math> pr <math>\leq</math> 200 bar  200 bar &lt; pr <math>\leq</math> 1000 bar  2 bar <math>\leq</math> pr <math>\leq</math> 20 bar  70 bar <math>\leq</math> pr <math>\leq</math> 700 bar    20 bar &lt; p <math>\leq</math> 5000 bar</p>
<p><b>Calibration of Electrical</b></p> <ul style="list-style-type: none"> <li>Signal Conditioner</li> <li>Data Acquisition System</li> <li>Multimeters</li> <li>Power Supply</li> <li>Oscilloscope</li> </ul>	<p>ICP/IEPE/Charge  DC/AC Voltage - DC/AC Current  DC/AC Voltage - DC/AC Current- Resistance  DC/AC Voltage - DC/AC Current  Time/Amplitude/Band Width</p>
<p><b>Calibration of Length</b></p> <ul style="list-style-type: none"> <li>Micrometer</li> <li>Analog/Digital Caliper</li> <li>Height Gauge</li> <li>Dial Gauge</li> </ul>	<p>0 <math>\leq</math> L <math>\leq</math> 300 mm / 300 <math>\leq</math> L <math>\leq</math> 500 mm  0 <math>\leq</math> L <math>\leq</math> 1000 mm  0 <math>\leq</math> L <math>\leq</math> 1000 mm  0 <math>\leq</math> L <math>\leq</math> 100 mm</p>
<p><b>Calibration of Temperature and Humidity</b></p>	<p>20 %rh-95 %rh  15°C / 35°C</p>





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