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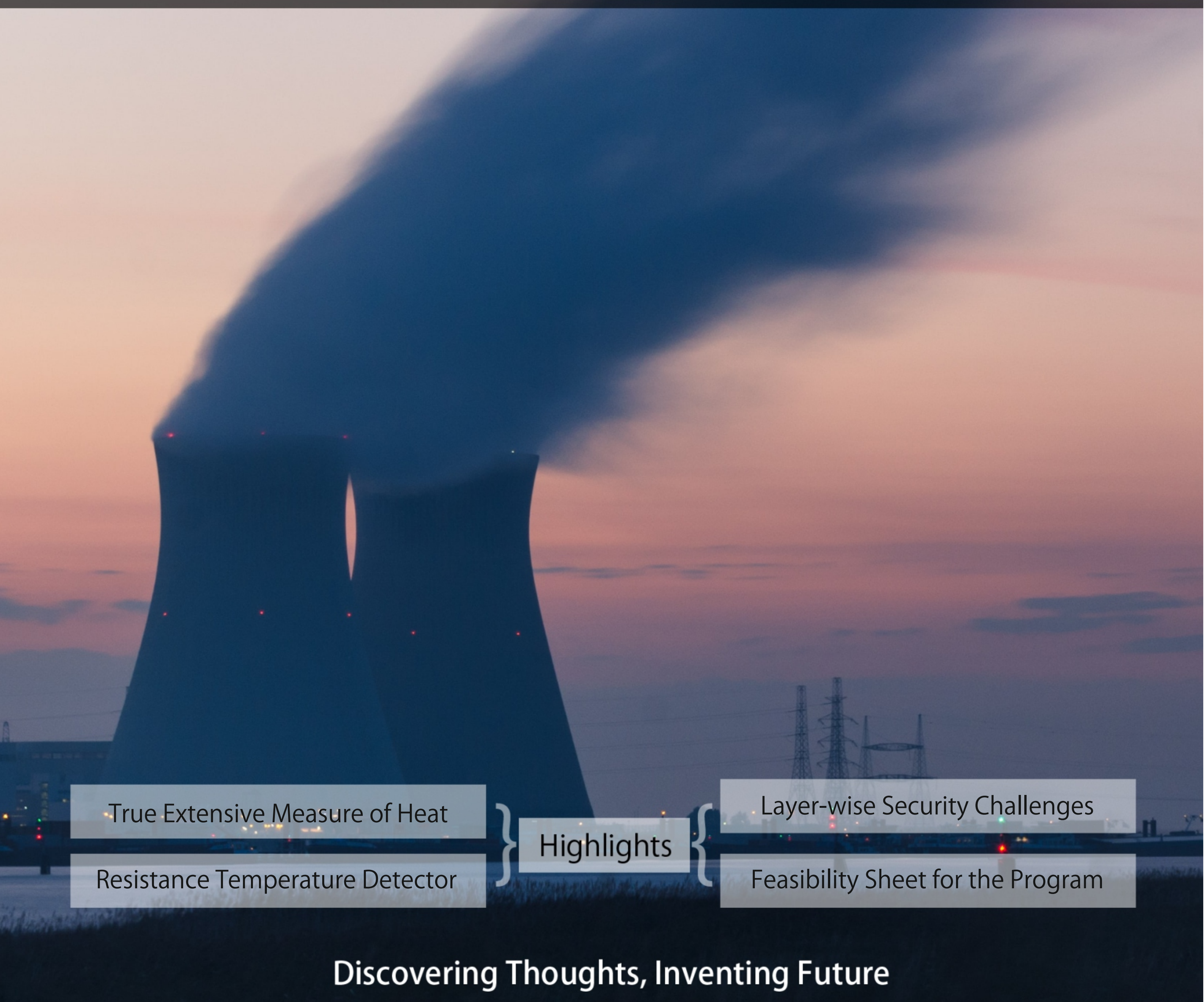

True Extensive Measure of Heat

Resistance Temperature Detector

Highlights

Layer-wise Security Challenges

Feasibility Sheet for the Program

Discovering Thoughts, Inventing Future

VOLUME 23 ISSUE 1 VERSION 1.0

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Resistance Temperature Detector (RTD) System in Nuclear Power Plant (A Short Review)

By Ali Zamani Paydar, Rahele Zadfathollah, Seyed Kamal Mousavi Balgehshiri & Bahman Zohuri

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Keywords: *instrumentation and control, resistance temperature detector, probabilistic risk assessment, advance reactor concept, generation IV, light water reactor, supercritical water reactor, pressurized heavy water reactor, sodium fast reactor, and molten salt reactor.*

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RESISTANCETEMPERATUREDETECTORRTDSYSTEMINNUCLEARPOWERPLANTASHORTREVIEW

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Resistance Temperature Detector (RTD) System in Nuclear Power Plant (A Short Review)

Ali Zamani Paydar [α], Rahele Zadfathollah [σ], Seyed Kamal Mousavi Balgehshiri [ρ] & Bahman Zohuri [ω]

Abstract- An RTD, or resistance temperature detector, is a sensor used to measure temperature. Made from either platinum, copper, or nickel, RTDs have a repeatable resistance vs. temperature relationship and an operating temperature range of –200°C to 850°C. RTDs contain a resistor whose resistance value changes as the temperature changes. They have been used for many years to measure temperature in laboratory and industrial processes and have developed a reputation for accuracy, repeatability, and stability. Platinum is a noble metal and has the most stable resistance-temperature relationship over the largest temperature range; it is therefore more common than copper or nickel RTDs. These devices are used extensively in the nuclear industry for monitoring the water temperature level in the core of nuclear reactor plants, such as the family of Light Water Reactors (LWRs). The RTD element does not respond instantaneously to changes in water temperature within the core of the reactor, but rather there is a time delay before the element senses the temperature change, and in nuclear reactors this delay must be factored into the computation of setpoints from the probabilistic risk assessment (PRA), specifically if we are using such a device in the new Advanced Concept Reactor (ARC) technology of Small Modular Reactors (SMRs) of Generation IV, also known as GEN-IV. In this short review, first of all, we will introduce this known technology in a simple way and then look into its application as in-core instrumentation and control (I&C) within these new-generation reactors.

Keywords: instrumentation and control, resistance temperature detector, probabilistic risk assessment, advance reactor concept, generation IV, light water reactor, supercritical water reactor, pressurized heavy water reactor, sodium fast reactor, and molten salt reactor.

I. Introduction

Temperature-type sensors are presently operating in many types of reactors of the water type, and they are in the form of either Resistance Temperature Detectors (RTDs) or Thermocouples (TC) inside a Stainless Steel (SS) tube sheath.

The Resistance Temperature Detector, or RTD, is a sensor whose resistance changes with temperature. The RTD, which is typically made of platinum (Pt) wire wrapped around a ceramic bobbin, has a physical property behavior that is more accurate and linear over a wider temperature range than a thermocouple.

RTDs have sensing elements, which are made of metal, typically platinum (Pt). The platinum metal in some RTDs is in the form of a wire wrapped around a mandrel (typically magnesium oxide) inside a stainless-steel tube with a magnesium oxide insulator between the mandrel and the inner wall of the sheath, as illustrated in Figure 1. [1]

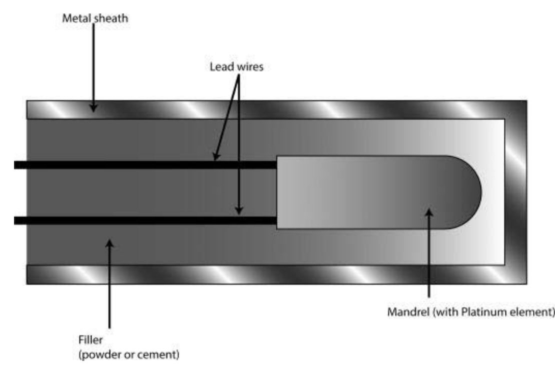

Figure 1: Resistance Temperature Detector [1]

Another different manufactured and designed type of RTD uses a platinum wire coil cemented to the interior wall of a hollow section of a metallic tube, as illustrated in Figure 2. [1]

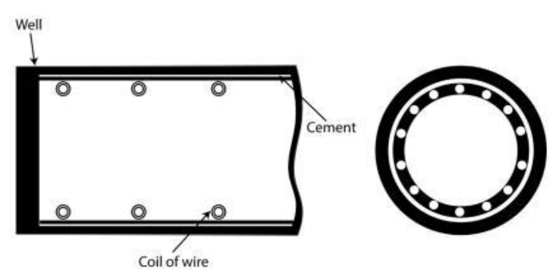

Figure 2: A Fast Response Resistance Temperature Detector [1]

This approach provides a very fast response to temperature measurement because the heat transfer resistance between the coil and the sheath is small.

Due to the thermal conductivity behavior of platinum (Pt), with a well-defined temperature resistance relationship, the built-in instrumentation of this kind of RTD measures the resistance and converts it to a temperature measurement using temperature versus the resistance calibration data. The resistance increases with temperature, and the temperature-resistance

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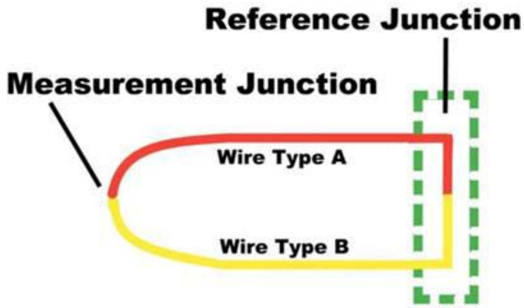
relation is almost linear. But the readout instrumentation accounts for the small non-linearity.

However, in the case of thermocouple (TC) type instrumentation, it comes with the implementation of two different types of dissimilar wires that are joined to form the thermocouple junction, as illustrated in Figure 3.



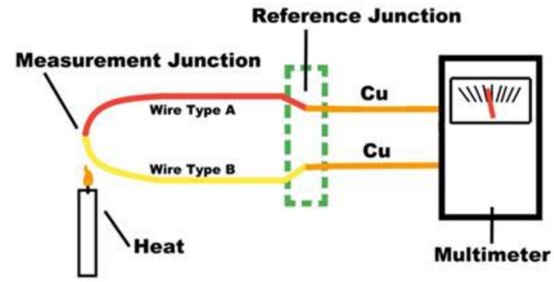
(Source: Courtesy of Enercorp)

Figure 3: Basic Thermocouple Concept

A thermocouple measures temperature, so technically, a thermocouple is a type of thermometer. Of course, not all thermometers are the same. Two different metals make up a thermocouple. Generally, it takes the form of two wires twisted, welded, or crimped together. Temperature is sensed by measuring the voltage. Heating a metal wire will cause the electrons within the wire to get excited and want to move. We can measure this potential for electrons to move with a multimeter. With this measurement, we can calculate the temperature.

In short, a thermocouple translates temperature energy into an electrical signal. This signal can be acted upon, perhaps directly by a person who is monitoring the thermocouple, but more likely by an automated system that observes, records, or uses the data to perform an action. Let us take a look at a diagram of a thermocouple to get an idea of how this instrument works.

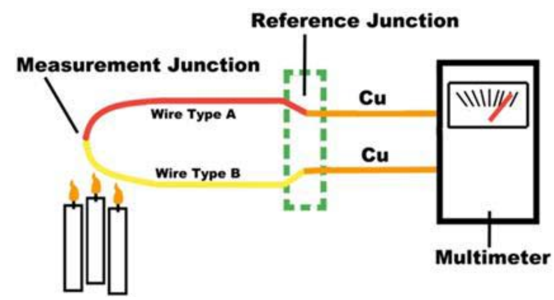
As one can see in Figure 3, a thermocouple is a relatively simple instrument. Two wires comprised of dissimilar metals are connected where the temperature needs to be measured. This connection is called the measurement junction. The other ends of the wires are also connected. but this time in an area where the temperature is known. This area is called the reference junction. Let us do a small experiment by heating one end of the thermocouple and adding a way to measure what happens. See Figure-4



(Source: Courtesy of Enercorp)

Figure 4: Heating a Thermocouple

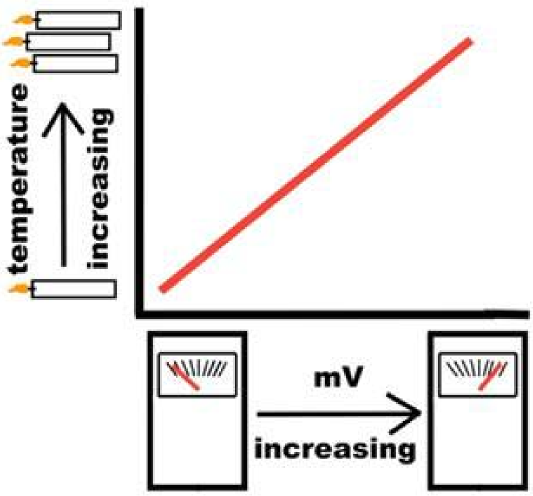
By applying heat to the measurement junction, we can cause electrons in the metal wire to excite and flow, producing a current. Since we are looking to measure the voltage of this current, we have connected the reference junction to a multimeter with copper wire. The current sensed by our multimeter gives us a reading in millivolts (mV). Let us increase the temperature at our measurement junction and see what happens to the reading on our multimeter. See Figure-5.



(Source: Courtesy of Enercorp)

Figure 5: Applying More Heat

As the measurement junction heats up more, the reading on our multimeter at the reference junction will increase correspondingly. The important part about the value of our multimeter is that it is a function of the difference in temperature between the two junctions. We can chart the relationship between the two variables. Thus, if we know the temperature of the controlled reference junction and can measure the voltage change as the measurement junction is heated, then, we can determine the temperature at the measurement junction. See Figure-6



(Source: Courtesy of Enercorp)

Figure 6: Charting Temperature vs. Voltage

Although a thermocouple does not directly tell us the temperature of the measurement junction, it does give us a voltage. This voltage is a readable electrical signal that is dependent on the difference in temperature between the measurement and reference junctions. You can graph or table this correlation between voltage and temperature. And we can reference the voltage signal to determine the associated temperature. Some aspects, like the type of wires used and the temperature of the reference junction, must remain constant. But ultimately, we have a repeatable process to measure temperature, one that is infinitely replicable.

Moreover, keep in mind that a thermocouple creates a voltage that depends on the temperature difference.

Between the junction and open end of the wires. So, a thermocouple voltage is a function of the temperature difference between the open end and the junction. The junction temperature is obtained as follows:

- ✓ Instrumentation measures the thermocouple voltage.
- ✓ Instrumentation measures the open-end temperature using a different type of sensor (usually a thermistor or integrated circuit sensor operating at the instrumentation which operates at ambient temperature).
- ✓ –Instrumentation calculates the voltage that would occur for a thermocouple with a junction at the ambient temperature measured at the instrumentation and the open end at 0^0C.
- ✓ –Instrumentation adds the measured thermocouple junction-to-open end voltage and the calculated ambient-to 0^0C voltage.
- ✓ Instrumentation uses the summed voltages to calculate junction temperature using standard calibration data for a thermocouple with the open end at 0^0C.

Thermocouples may be used for in-core coolant temperature measurements. Type-K thermocouples (Chromel - Alumel) or type-N (Nicrosil - Nisil) are suitable. Type-N is usually preferred for high temperature measurements because of a de-calibration tendency in Type-K. Thermocouples may have the junction insulated from the sheath or have the thermocouple wires attached to the sheath as illustrated in Figure-7 [1] (a grounded junction thermocouple). Grounded-junction thermocouples have faster time response than insulated junction thermocouples. [1]

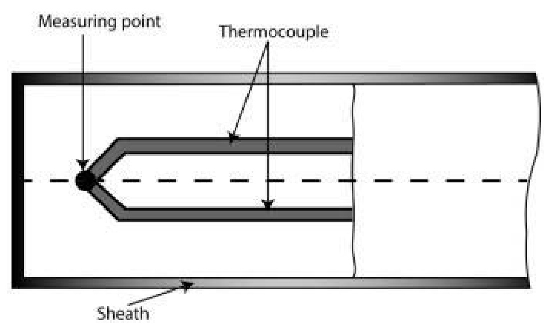
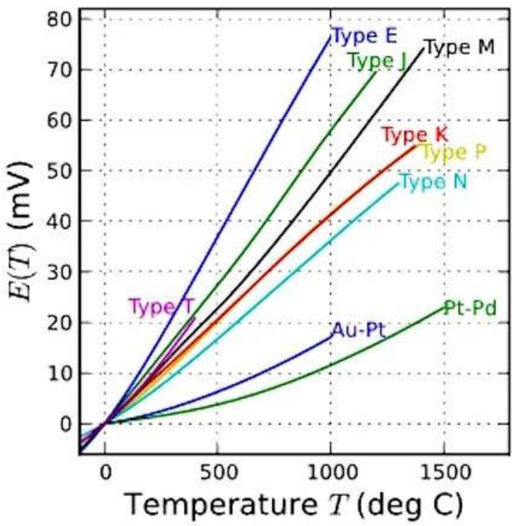


Figure 7: A Sheathed Thermo-Couple Configuration [1]

In summary, thermocouples are commonly used for measuring higher temperatures and larger temperature ranges.

To summarize how thermocouples work, any conductor subjected to a thermal gradient will generate a small voltage. This phenomenon is known as the *Seebeck effect*. The magnitude of the generated voltage is dependent on the type of metal. Practical applications of the Seebeck effect involve two dissimilar metals that are joined at one end and separated at the other end. The junction's temperature can be determined via the voltage between the wires at the non-junction end.

There are various types of thermocouples. Certain combinations of alloys have become popular, and the desired combination is driven by variables including cost, availability, chemical properties, and stability. Different types are best suited for different applications, and they are commonly chosen based on the required temperature range and sensitivity. Figure-8 shows a graph of thermocouple characteristics.



(Source: Courtesy of wikipedia.org)

Figure 8: Thermocouple Characteristics

"Dynamics and Control of Nuclear Reactors" presents the most recent knowledge and research in the new generation of reactor dynamics (i.e., Advanced Reactor Concepts (ARC)), where instrumentation and control (I&C) play an important role in ensuring the safe and economic operation of nuclear power plants.

The dynamic characteristics can be sensible in the family of Light Water Reactors (LWRs) such as Pressurized Water Reactors (PWRs), Boiling Water Reactors (BWRs), Supercritical Water Reactor (Super-Critical Water-cooled Reactors (SCWRs), Pressurized Heavy Water Reactors (PHWRs) and Molten Salt Reactors (MSRs). It also provides pertinent, but less detailed information on Small Modular Reactors (SMRs), such as Sodium Fast Reactors (SFRs), and Gas-Cooled Reactors (GCRs).

II. The Basics of a Resistance Temperature Detector (RTD)

Resistance Temperature Detector (RTD) operate on the principle that the electrical resistance of a metal changes predictably in a linear and repeatable manner with changes in temperature. The traditional RTD element is constructed of a small coil of platinum, copper, or nickel wire wound to a precise resistance value around a ceramic or glass bobbin. The winding is generally of the helix style for industrial use.

The most common RTD element material is platinum, as it is a more accurate, reliable, chemically resistant, and stable material, making it less susceptible to environmental contamination and corrosion than other metals. It is also easy to manufacture and widely standardized, with readily available platinum wire available in very pure form with excellent reproducibility of its electrical characteristics. Platinum also has a higher melting point, giving it a wider operating temperature range.

"For an RTD sensor, it is the wires, which connect to the sensing element, and the wire insulation, which generally limit the maximum application temperature of the sensor." Measuring the temperature requires accurate resistance measurement. To measure the resistance, it is necessary to convert the resistance to a voltage and use the voltage to drive a differential input amplifier. "The use of a differential input amplifier is important as it will reject the common mode noise on the leads of the RTD and provide the greatest voltage sensitivity." [2]

The RTD signal is typically measured by connecting the RTD element to one leg of a Wheatstone bridge, either excitable by a constant reference voltage or in series with a precision current reference, and measuring the corresponding Intensity Resistance (IR) voltage drop. The latter method is generally preferred as it has less dependence on the reference resistance of the RTD element.

Furthermore, temperature is one of the most routinely measured physical quantities in industry, in particular in the core of nuclear water reactors while they are in operation mode, and the safety of their operation period is very important from a control room perspective. Other industries, for instance, food and beverage manufacturers, must maintain certain temperature conditions to ensure that their products are in compliance with Food and Drug Administration (FDA) regulations and to prevent spoilage. The chemical industry must carefully monitor temperature to control reaction kinetics, prevent runaway reactions and side reactions, and optimize energy usage. Companies such as Control Automation are providing a lot of commercialization of this device to so many industries that are in need of such instrumentation, and it can also be scaled up to meet the needs of the nuclear industries as well.

As we have stated above, there are many ways to measure temperature, most of which take advantage of hotter atoms that have more energy and thus vibrate quicker. Thermal expansion methods of temperature detection, such as the expansion of mercury (or colored alcohol) in a thermometer, are evidence of this faster vibration.

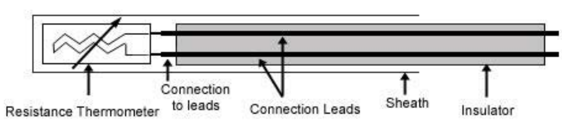
The electrical response of materials changes with temperature as well. If two dissimilar metals are in contact, they will generate a voltage called the Seebeck voltage. The Seebeck voltage will vary linearly with temperature. Thermocouples measure temperature based on this effect.

As a material heats up, its electrical resistance increases. The atoms in the material vibrate faster, and thus, flowing electrons are more likely to be repulsed by existing electrons trapped in the orbits of these atoms. As anyone shooting a basketball knows, it is easier to shoot the basket if the defender is not flailing their arms in the way; the same is true with an electron trying to pass through a material. If the temperature were to drop to absolute zero (no atomic motion), the resistance would be very low, as the electrons would not encounter the random motion of these atoms and could zip through easily. See Figure 9, where the RTD is inside these metal housings.

(Image used courtesy of El-Sensor)

Figure 9: Several Commercial RTD Probes

A RTD is simply a piece of metal wire, usually platinum (Pt), with a known resistance characteristic at zero degrees Celsius, as shown in Figure 10.



(Image used courtesy of Psanderson)

Figure 10: Diagram of a Resistance Temperature Detector (RTD)

It also must have a predictable resistance with a change in temperature. This change in resistance is described by a linear equation. For example, one of the most common RTDs on the market is the "Pt100," which stands for a platinum wire with 100 **Ω** of resistance at 0 ^{0}C. This RTD can also be described by the equation:

$$R = (0.385\ \Omega\ ^0C)\ T + 100\ \Omega$$

Where R is the resistance and T is the temperature. Solving for T:

$$T = (2.597\ \Omega\ ^0C)\ R - 259.7\ ^0C$$

Note that: The type of Platinum RTD is often indicated with the abbreviation "Pt" followed by a number, e.g., "Pt100". The number indicates the Platinum resistance at 0 ^{0}C. The Temperature Coefficient of Resistance (TCR) of the most common platinum RTD is 0.00385/(0C). The TCR indicates the average resistance change per zero Celsius and can be seen as a sensitivity parameter. In other words, the resistance of the most common platinum RTD changes by 0.38% per 0C [3].

While the resistance change can be measured with a multimeter, a much more common way to measure a resistance change is to use a “Wheatstone Bridge” circuit. A constant-voltage bridge circuit similar to that used with strain gauges is usually used for sensing the resistance change that occurs. Figure-11 shows a Wheatstone Bridge for reference. The RTD acts as an adjustable resistor and thus could replace Rx. As the resistance changes, the voltage measured across “null” will also change.

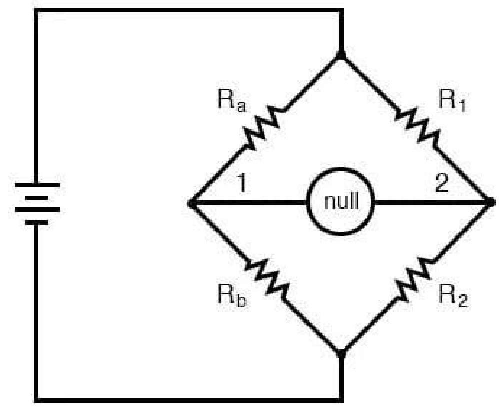


Figure 11: Wheatstone Bridge

One could use their knowledge of circuit analysis and the linear equation for the RTD to calculate the temperature change for a given voltage change. A more common way to determine the temperature is through a calibration procedure.

III. Resistance Temperature Detector (RTD) Calibration

Place an RTD in an ice water bath to calibrate it. When the voltage stops changing, take note of the temperature (measured with a calibrated thermometer) and voltage at the Wheatstone Bridge circuit, as shown in FIGURE 12. Repeat this process with room-temperature water, heated water, boiling water, etc. The more data points, the better. From there, one can plot these points and find a best-fit line that will describe the relationship between voltage and temperature.

Figure 12: A Way to Calibrate an RTD

The calibration procedure will take some time to perform. However, one of the big advantages of calibration is that it automatically accounts for the temperature change on the nearby wiring, as its resistance is changing, just like the RTD's resistance is changing.

IV. Advantages and Limitations of Resistance Temperature Detectors (RTDs)

RTDs can provide an accurate temperature measurement, provided the temperature does not change rapidly. Therefore, they can be used for repeatable, steady-state reactions and processes.

As we stated before, RTDs are slower to respond than other temperature sensors. In order to understand why, consider that there are three modes of heat transfer: conduction, convection, and radiation.

Conduction requires a temperature difference to flow heat directly between two solid materials, such as touching a hot stove. Convection is heating transfer due to moving fluid, such as blowing on hot soup. Radiative heat transfer deals with which wavelengths and at what intensity are emitted from an object, such as feeling the heat from an open fire.

The RTD does not directly touch the heated environment, and so conduction is limited. RTDs are often housed in an evacuated chamber, limiting convection. Radiative heat transfer is possible, though it is much more efficient at high temperatures. Therefore, all three methods of heat transfer are much slower in an RTD.

Another consideration is the resistance of the lead wires that connect the RTD to your measurement. The resistance of these leads will increase with temperature as well. If the leads are replaced with longer ones, the resistance will increase and make up a larger percentage of the total resistance.

There are several ways to overcome the problems presented by the lead wires. In general, keep lead wires short and calibrate and spot-check the RTD whenever possible. If the system is calibrated with the RTD leads, it will account for the resistance of the leads at specific temperatures. Also, RTDs can be plugged into wireless transmitters for data logging instead of running longer leads.

RTDs are just one method of measuring temperature. They are particularly useful when temperatures need to be accurately measured and recorded but aren't expected to change very quickly.

V. Resistance Temperature Detectors for Advanced Reactors

It is well known that the response time of RTDs and thermocouples is subject to change over time.

Many factors contribute to this degradation; for example, vibration can cause RTDs and thermocouples to move out of their thermowells and result in an increase in response time. Temperature variations can also result in changes in sensor response time. For example, inherent voids in sensor insulation materials can expand or contract and cause the response time to change. For these and other reasons, the response time of RTDs and thermocouples is measured periodically in nuclear power plants (see Figure 13) [4].

The harsh environments of advanced reactors, such as high temperatures, high levels of nuclear radiation, the potential for corrosion, and limited access to sensors for maintenance, are just a few examples of instrumentation challenges that must be designed, developed, and qualified for advanced reactors. [5]

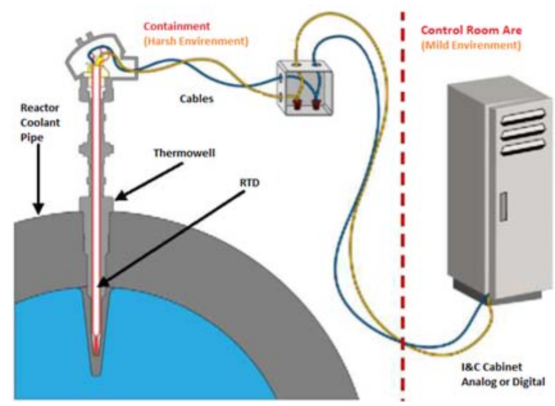


Figure 13: Illustration of Temperature Sensor System and Connections in a Nuclear Power Plant

Furthermore, the operating cycles of most advanced reactors are expected to be much longer than those of conventional plants, adding to the need for instrumentation that can maintain calibration and response time over extended intervals. [5]

Advanced reactors, with respect to their operating characteristics, can have high core outlet temperatures, unique primary coolants, significantly longer refueling intervals, and complex geometries that complicate the deployment of conventional Instrumentation and Control (I&C) sensors.

For example, Sodium, unlike water, is a non-moderating coolant and thus allows for a fast neutron spectrum. A shorter neutron lifetime and magnitude of delay coefficient result in a reactor that is dynamically more sensitive than a conventional pressurized water reactor (PWR). Thus, I&C sensors in sodium-cooled reactors must be designed for reliable operation at high temperatures > 500 oC), have a fast response in order to maintain stable reactor control and timely shutdown, and provide diagnostic capability in case of inadvertent reactivity addition or equipment problems. [5]

RTDs have a long operating history in conventional PWRs, and their failure modes and degradation mechanisms are well understood. However, they were not designed to withstand prolonged exposure to elevated temperatures, high radiation, and the corrosive coolants expected in the primary systems of advanced reactors. as well as frequent conventional RTD maintenance or replacement to combat increased calibration drift or premature response time degradation is not practical for advanced reactors with extended operating cycles. Therefore, new I&C sensors must be developed and qualified for service in advanced reactor environments.

VI. Conclusion

As we stated in the abstract of this short review article, the Resistance Temperature Detector (RTD) element does not respond instantaneously to changes in water temperature, but rather there is a time delay before the element senses the temperature change, and in nuclear reactors this delay must be factored into the computation of safety setpoints. For this reason, it is necessary to have an accurate description of the RTD timing response. This Safety Evaluation (SE) is a review of the current state of the art of engineers concerns and research by describing and measuring this time response that is not real-time but at least near real-time.

Historically, the RTD time response has been characterized by a single parameter called the Plunge time constant, or simply the Plunge τ. The Plunge τ is defined as the time required for the RTD to achieve 63.2% of its final response after a step temperature change is impressed on the surface of the RTD. Such a temperature change can be achieved by plunging the RTD into a heat sink, such as water, oil, ·sand, or molten metal. When τ is measured by this means, the technique is called the plunge test method. For more information, refer to this references the U.S. NRC. [6]

However, bear in mind that the time response is not only a function of the RTD itself but also depends on the properties of the thermowell and the thermal characteristics of the medium in which the thermowell or RTD is immersed.

The thermal properties of all these components change with temperature, and the heat transfer properties of the medium (water) change with flow velocity.

The match between the RTD and the thermowell affects the time response, and even the slight change in match that occurs when an RTD is removed from a thermowell and placed back in the same well can significantly change the time response. Thus, it is important to simulate service conditions as closely-as possible, when testing the RTD time response.

Furthermore, there are a variety of Resistance Temperature Detectors (RTDs) sensors that are specially designed to ensure precise and repeatable temperature measurements of media such as water in the reactor core.

Many companies in this industry and RTD manufacturing build sensors to meet the most demanding industrial applications while providing customers with a lower total cost of ownership.

As it is, these detectors are frequently used in many industries. Care must be taken to eliminate moisture, and vibration effects can be troublesome as well. Companies like Thermo Sensors Corporation provide the utmost in the current state of the art in materials, techniques, and research, and this RTD features lifetime moisture free as well as excellent vibration resistance.

Bottom line, Resistive Temperature Detectors, also known as Resistance Thermometers, are perhaps the simplest temperature sensors to understand. RTDs are similar to thermistors in that their resistance changes with temperature.

However, rather than using a special material that is sensitive to temperature changes—as with a thermistor—RTDs use a coil of wire wrapped around a core made from ceramic or glass.

The RTD wire is made of pure material, typically platinum, nickel, or copper, and the material has an accurate resistance–temperature relationship that is used to determine the measured temperature.

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Feasibility Sheet for the Program The Maritime Technological Surveillance carried out through Sensor Networks based on Fixed and/or Semi-fixed Unmanned Platforms

By Dr. Diego Abbo

Premise- The safety in general which includes those of the maritime areas of interest must satisfy the principle of the so-called safety equation:

$$Tm >> Ta + Ti$$

Dove:

Tm: It represents the time it takes for the threat to complete its mission.

Ta: It represents the alert time in which you are aware that the threat is completing its mission;

Ti: It represents the time to engage the threat before it has completed its mission.

The times indicated (Ta and Ti) can be represented in naval scenarios with the triangle DPE (Detection, Positioning and Engagement).

The DETECTION in the present case indicates the discovery but not the location (POSITIONING) which may or may not be followed by subsequent locations in a tracing eventuality.

The last certain position of the target is defined, in the air and naval field, as DATUM.

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FEASIBILITYSHEETFORTHEPROGRAMTHEMARITIMETECHNOLOGICALSURVEILLANCECARRIEDOUTTHROUGHSENSORNETWORKSBASEDONFIXEDANDORSEMIFIXEDUNMANNEDPLATFORMS

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I. Premise

The safety in general which includes those of the maritime areas of interest must satisfy the principle of the so-called safety equation:

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In the current geostrategic scenario, the threat must only be seen in a direct war confrontation. In the other sense the target, in the DPE Triangle, enlarges the concept threat. In fact, in the rescue missions of human life at sea the threat must be understood only as the impediments to act to complete the rescue.

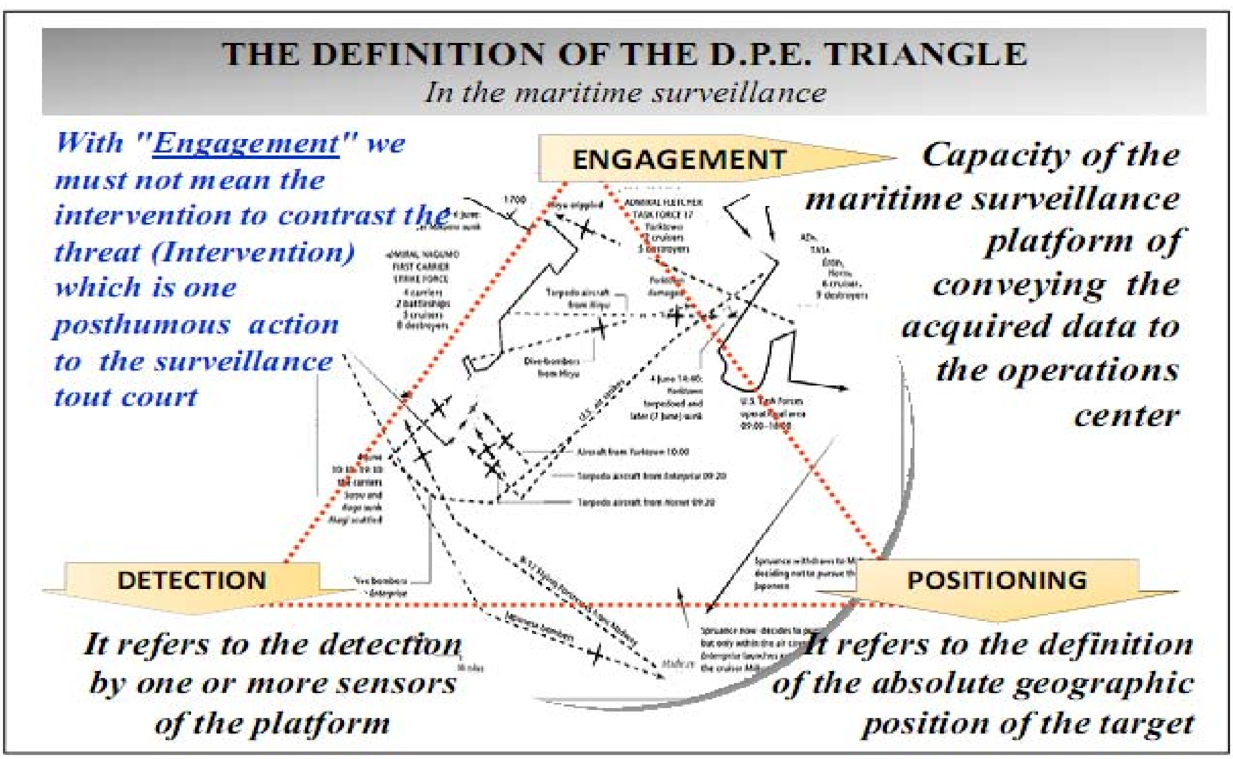

Figure 1: The image refers to the battle of Midway (4÷7 June 1942) where the two opposing fleets never came into direct contact but the victory of the USA was made possible by the parameters of the D.P.E. in force at that time

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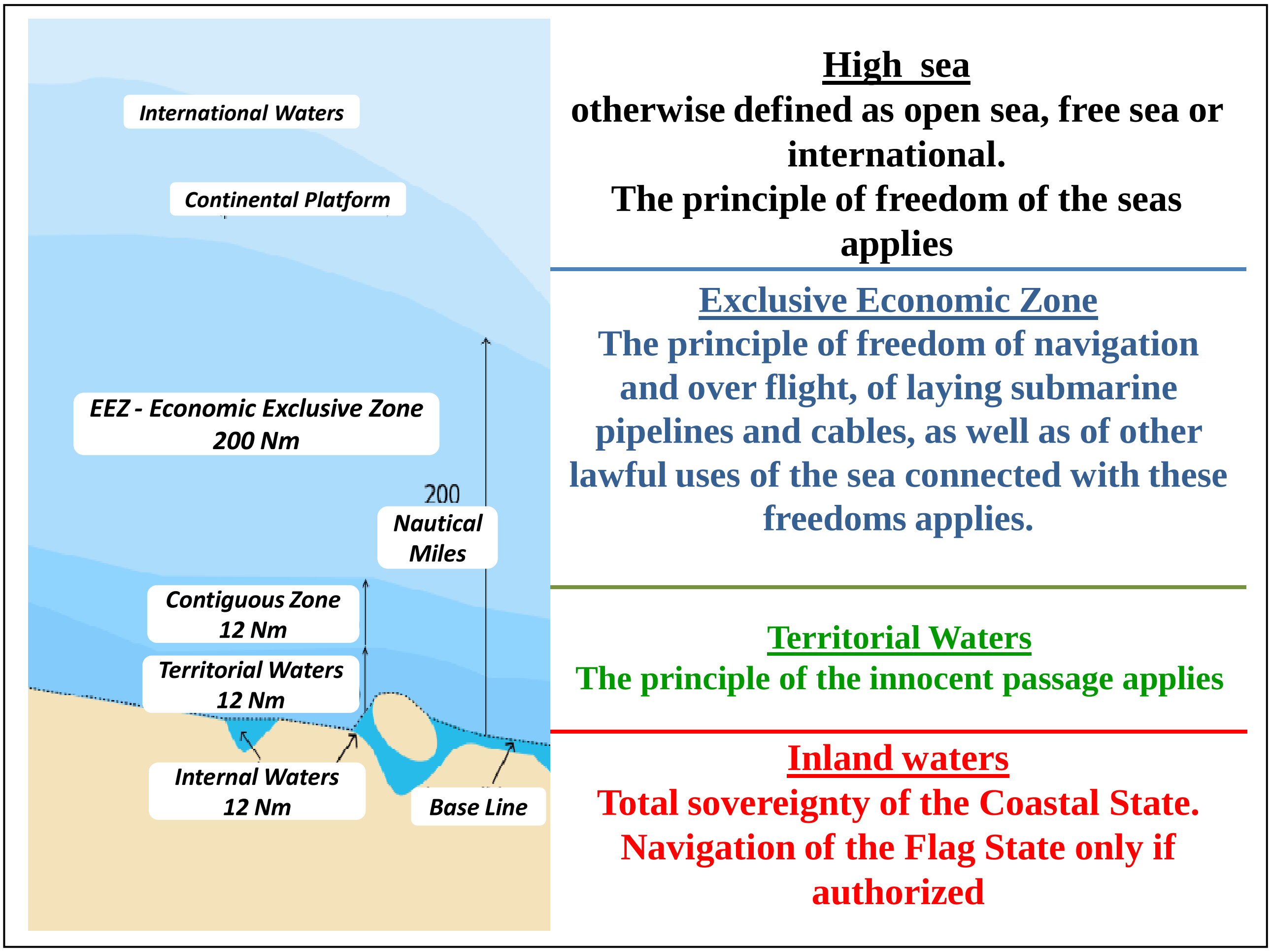

Figure 2: The subdivision of the sea according to the Montego Bay Convention

Therefore ENGAGEMENT has considerable diversifications according to previously planned needs.

The mission of maritime surveillance therefore relates to the discovery and localization with the related *Ta* and *Ti*.

Therefore, the optimal surveillance is reached when, in the area of interest, there is a total geographical coverage of the DPE Triangle parameters for 24 hours a day and 7 days a week.

II. The Sea Arena

The global maritime surface is divided into legal zones in which the duties and rights of the States, that have cause, are established according to the Montego Bay Convention (UNCLOS - *United Nations Convention on the Law of the Sea*).

In the following Figure 2 the areas in question are identified and each one corresponds to a comparison matrix between the rights/duties of the coastal and flag states respectively.

In the current maritime scenario, surveillance in the Exclusive Economic Zone (EEZ) highlighted in Figure 3 according to a vertical elevation has a particular value.

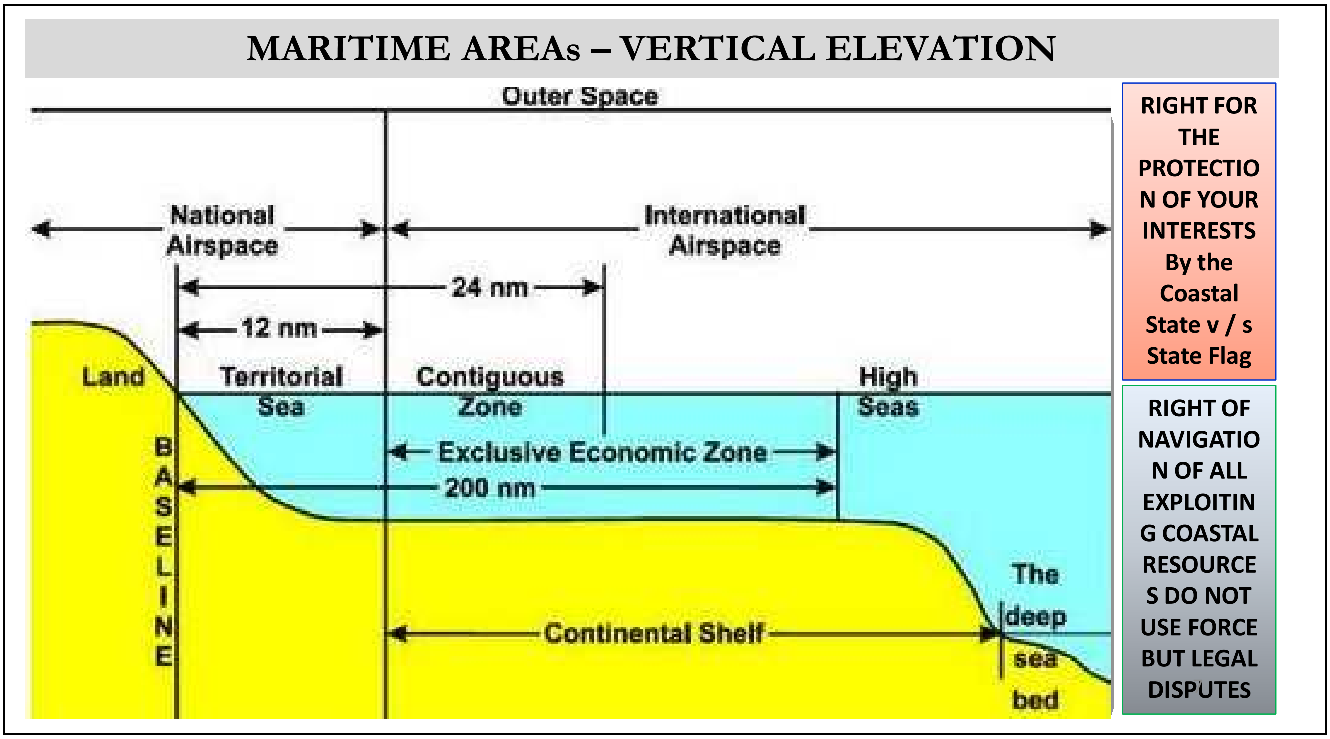

Figure 3: The vertical elevation of the maritime areas of UNCLOS

Figure 4 highlights the probable EEZ of Italy at the end of its determination by the Italian Government.

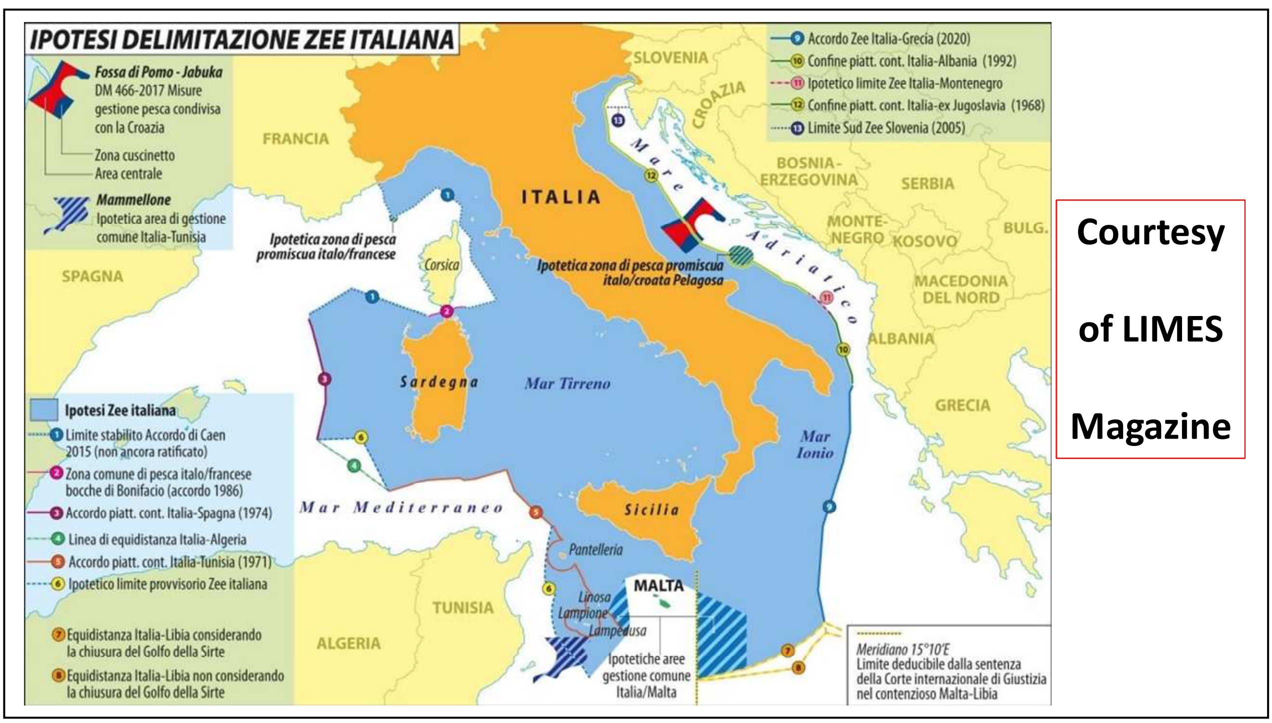

Figure 4: The possible ZZE of Italy at the end of the parliamentary process underway for its determination

The coastal state, while having to guarantee the freedom of navigation and over flight of the flag states, has the exclusive ownership to establish platforms for the exploitation of resources relating to both the water column and the seabed.

In the specific case, Italy should guarantee freedom of navigation in the EEZ but should also protect all commercial platforms producing renewable energy and exploiting the resources of the seabed and the overlying water head.

The point is the preventive defense of national maritime interests with a capillary surveillance system that adopts various forms and levels of technology.

The current systems used in the EEZ are not unmanned fixed platforms but are aircraft (unmanned or manned) used for surveillance which, due to costs, does not satisfy the requirement of continuous stay on site.

Furthermore, they are unable to satisfy the need for knowledge and awareness of the maritime situation in order to exercise their direct control or sovereign authority over the low-cost, low-manned territory of interest.

There is therefore a need for a new type of strategy based on newly developed resources, one that can take advantage of remote decentralized distributed sensors and network architecture of the type C3 (Command, Control and Communications), which is able to reduce the need to deploy high-value manned resources to perform maritime surveillance and to provide persistent and permanent awareness of the entire maritime situation.

The proposed type of resource will be able to host existing and emerging sensors and other required technologies in a cost-effective and operationally robust way.

A fundamental requirement for this new type of resource is to be able to carry out long-range maritime surveillance and projection towards the sea.

Furthermore, this type of resource or asset will be of the floating type, therefore semi-fixed, able to be redistributed and therefore reconfigure the spatial arrangement of the network within the national offshore areas of interest.

The platforms aimed at the purpose and therefore proposed are the following:

- BUOY not anchored (to be redeployed)
- Anchored larger BOA (to be redeployed)
- Instrumented platforms to be associated already existing on site or possibly to be deployed;
- Dedicated wind turbines;
- Oil platforms already existing on site.

The aforementioned platforms must be such as to be able to carry radar systems, ESM systems, sonar and hydrophone systems, electro-optical detection devices, magnetic anomaly detectors and particular systems of both communication and specific power supply aimed at the platform.

For structures dedicated to wind turbines or oil platforms, the possibility of docking various types of "unmanned" platforms (UxVs) will also be provided.

Current technologies, enslaved by renewable energies geared towards miniaturization, can provide a very profitable scenario solution.

However, these solutions must have optimal integration on satellite coverage and those provided by on-site platforms.

III. Buoys not Anchored and Anchored

The buoy that is not anchored is of minimal size and left adrift at sea after being placed on it, on contingency needs, by fast aircraft or ships.

The purpose of the buoy or network of unanchored buoys is to contribute to Maritime Surveillance in order to saturate the area of interest.

The buoy structure must be able to appropriately embark the various sensors aimed at maritime surveillance.

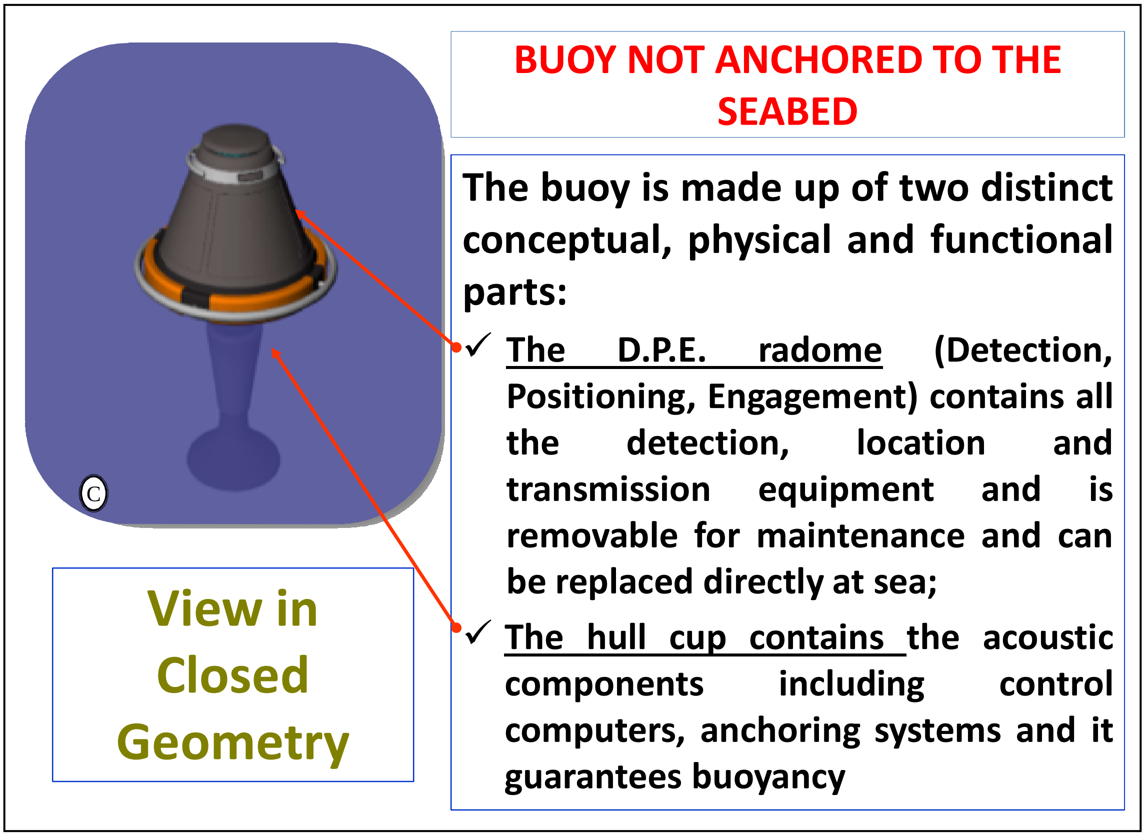

Figure 5: Image of the buoy not anchored in the "closed geometry"

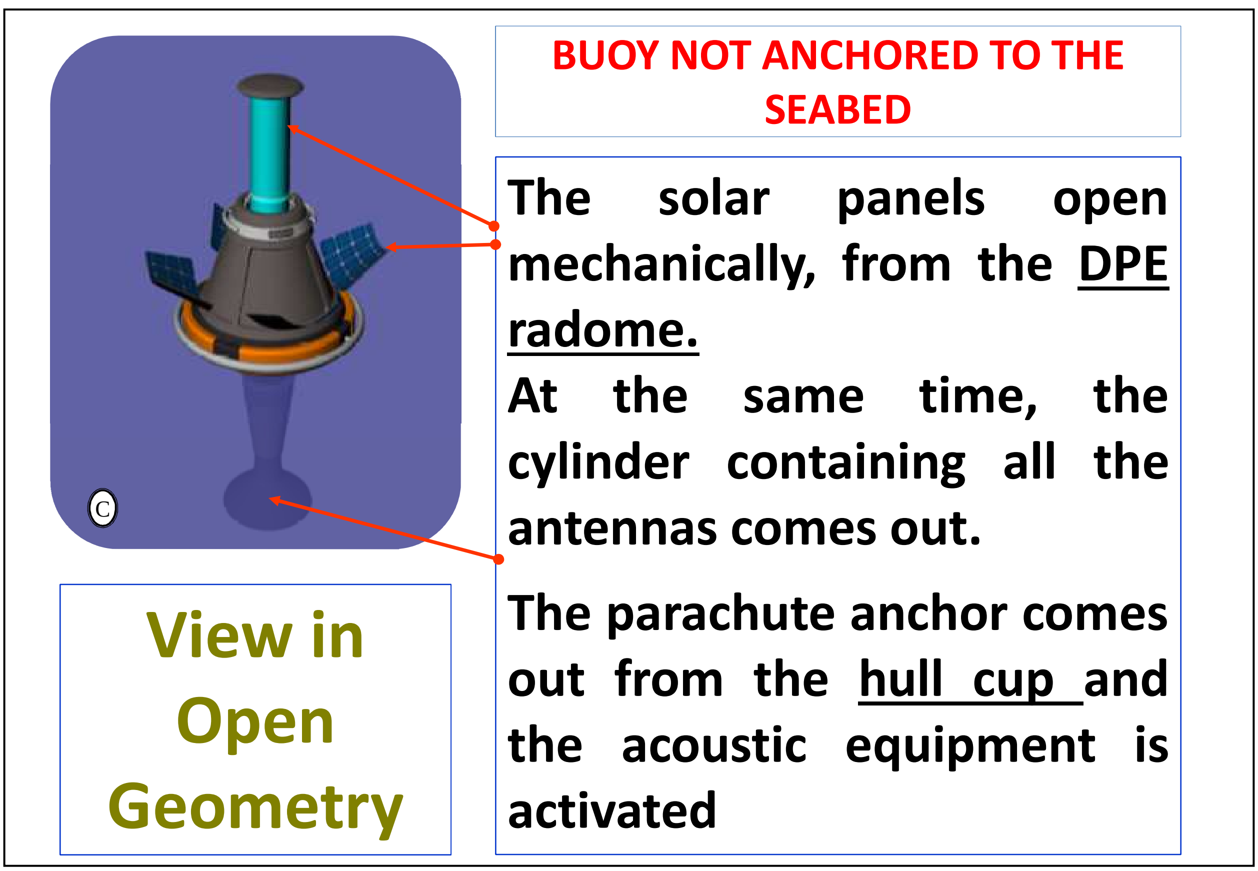

Figure 6: Image of the buoy not anchored in the "open geometry"

It will be necessary to provide for the construction of both the power supply system, based entirely on renewable energy (photovoltaic), and the communication system including its own positioning.

As regards the power supply system, this must be achieved by means of suitably placed solar cells which will act as a source of energy for the buoy by appropriately storing and managing the energy collected so as to allow the on-board systems to operate correctly and the communication system to receive and transfer the data operated by the sensors.

Conceptually, the buoy in question consists of two distinct functional, physical and conceptual parts: the radome D.P.E. and the hull cup (Figure 5).

The buoy has an open configuration in which the openings of the solar panels allow the satisfaction of the energy needs of the equipment on board (Figure 6).

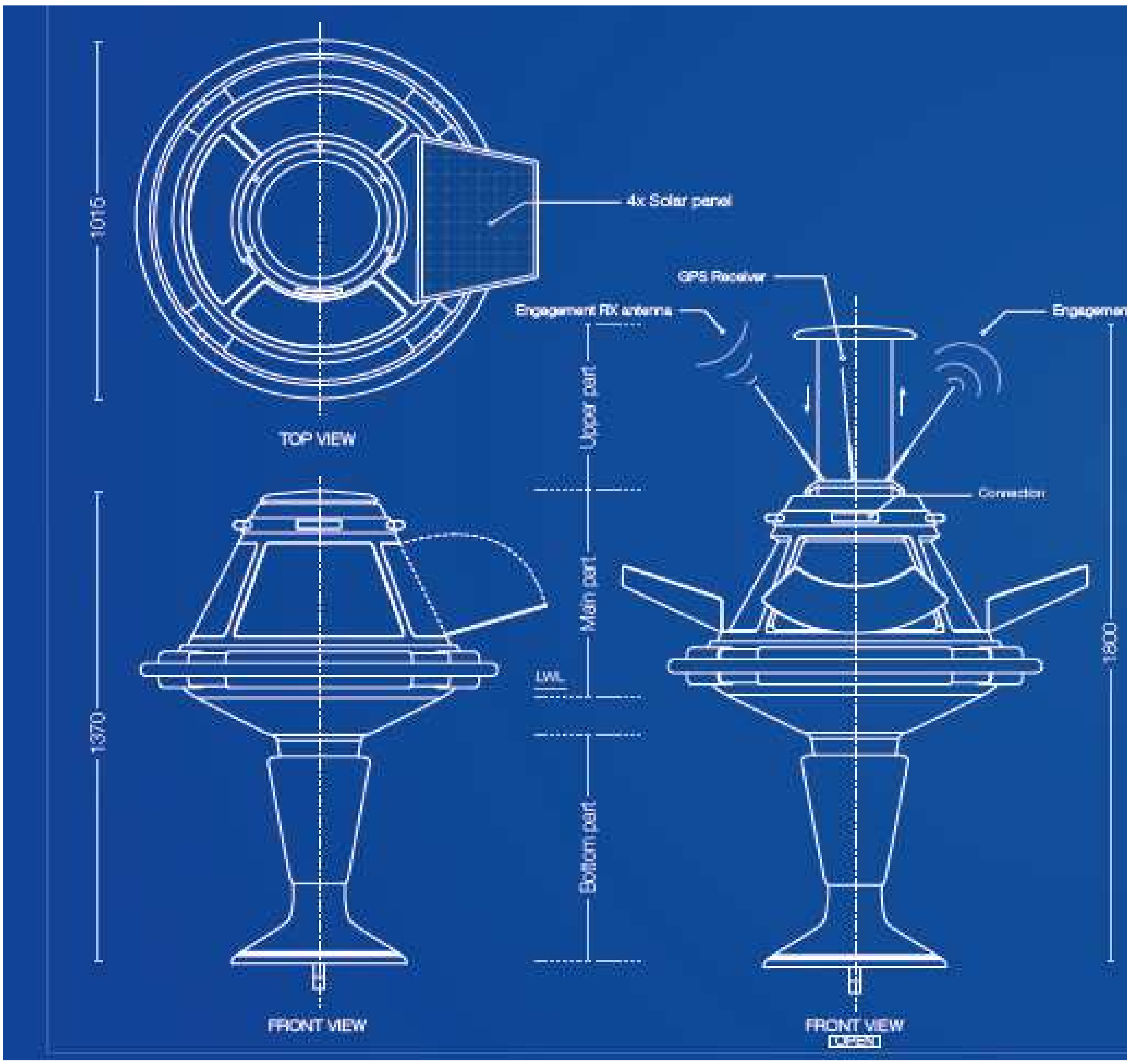

Figure 7: Dimensions of the buoy not anchored

The dimensions of the non-anchored buoy are enclosed in a cylinder with a radius of 1016 mm for a height of 1370 mm in the closed version and 1800 mm in the open version (Figure 7).

The anchored buoy, having the winch and the cable to "spin the anchor on the seabed, is enclosed in a cylinder of the same base but with a higher height.

In fact, the dimensions of the anchored buoy are enclosed in a cylinder with a radius of 1016 mm for a height of 1800 mm in the closed version and 2010 mm in the open version.

For the purposes of maritime control, they will operate on three physical surveillance volumes:

- The surface of the sea,
- The underlying water column
- The airspace above.

The Radome D.P.E. of both buoys contains the following equipment:

- A floating state with highly stable assets;
- An anchoring system in the sea that is not of a fixed type;
- A GPS locator
- An independent power supply system;
- A battery to store electricity;
- An independent transmission/reception system for continuous communication with the Command and Control Center or with a Digital Platform.
- A surveillance radar with remote/local activation/ deactivation device;
- An imaging device;
- A passive interception system of electromagnetic waves in the electromagnetic band with a local disabling device in case of power failure;
- A sonar that uses active acoustic energy;
- A hydrophone;
- A magnetic anomaly detector;
- A system that, for the surface target, integrates passive acoustic and active electromagnetic DPE information in order to have better maritime surveillance parameters.

Obviously the range of action of the aforementioned DPE triangle (Detection Positioning Engagement triangle) will differ for each of these three areas according to the limits of the sensors used and the physical characteristics of the three environments.

Last but not least, the "Engagemernt" function of the triangle D.P.E. allows the forwarding, in real time, of the data collected through communication devices embarked on the aforementioned platforms.

The communication system can be both of the satellite type and also of the VHF type and therefore capable of sending data to Command and Control Centers based on land and / or installed on ships and / or aircraft.

IV. The Characteristics of the "Radome D.P.E."

The current state of the art of technology, in the current availability of Italian companies such as those included in the Italian Group of High-Tech Manufactures, (IGHTM) business network, allows the previously listed equipment to be operated on the buoy.

These are put into operation when the buoy in the water assumes an “open configuration and becomes in fact operational.

Technically, the electromagnetic receiver, located in the emerged part of the buoy, is made up of antennas, a Radio Frequency Front-End and a broadband processor capable of identifying the electromagnetic scenario relating to the targets detected both underwater and on the surface.

The active and passive acoustic sensors are positioned below the waterline of the buoy and are able to provide information relating to both submerged and surface navigation targets.

Each "radome D.P.E. it contains a satellite positioning system (GPS) so that it can transmit its position during the operational phase (“Positioning” function of the triangle D.P.E.).

The functions that the electromagnetic receiver are able to transfer for each single detected emission: both that of the arrival direction and that of the parameters with which the emission is recognized on the basis of a programmable library that can also be updated through a system of "remote control".

The frequency band in which the receiver operates is between 2 and 18 GHz.

As mentioned, it must have an autonomous electricity production system that uses renewable solar sources and an electric storage battery.

The passive system of interception of electromagnetic waves consists of a digital goniometric receiver. It is an ultra-modern device of small dimensions, suitable for detecting electromagnetic emissions present in an extremely wide range of frequencies, as is of interest for digital electronic warfare receivers.

The Receiver, by means of its four antennas and the relative receiving channels, is able to measure the amplitudes and phases of the signals received by the antennas and to determine the direction of arrival of the various signals and also to detect all the characteristics of the electromagnetic emissions.

Important functions of the receiver are the detection of the characteristics of the detected radars such as

- Target Distance
- Direction of (Signal) Arrival
- Carrier Frequency
- Pulse Width
- Pulse Repetition Frequency
- Chirp Duration
- Chirp Delta Frequency
- Barker Code Number
- Analog Demodulation (for telecommunication)
- Digital Demodulation (for telecommunication)
- Detected Modulation Type (AM; FM; QAM; etc.)

This type of receiver, being able to operate in different modes, will be classified as a "Multifunctional Receiver". In particular, it can be set up to operate in the following operating modes:

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- *"Wide Openmode"* – It consists of panoramic reception in the whole band from 100 MHz to 18 GHz. In this operating mode there is the maximum probability of interception for all emissions at all frequencies of the band.
- *"Channelized" mode* – It consists in channeling the entire band 100 MHz ÷ 18 GHz in sub- bands from 100 MHz to 1 GHz in order to explore one or more sub-bands with greater frequency and speed.
- *"Narrowband" mode* – It consists of tuning for a narrow frequency or sub-band inside the main band from 100 MHz to 18 GHz. In this operating mode, maximum receiver sensitivity and continuous signal demodulation are obtained.

The complete equipment consists of the following sub-assemblies:

Quadruple broadband antenna, RF Front-End, Digitization system, numerical processing Digital Data Output Circuit.

Specifically:

- *Quadruple Antenna* - is a group of broadband antennas of the "Plane spiral" or better Sinuous" type oriented to receive from the four cardinal points.
- *RF Front-End* - includes Low Noise Amplifiers for sensitivity, 0.1 to 18 GHz Band Filter, Fast Dynamics Translator.
- *Digitizing subsystem* - Provides for converting received analog signals into digital data.
- *Numerical Processing* - It consists of a digital circuit that includes a microprocessor, an FPGA, a fast memory, the firmware installed provides for the fast control of operations.
- *Data Display* - High resolution graphic display for viewing all data and for setting up appropriate actions.
- *Digital Data Output Circuit* - with its own BUS, it appropriately distributes the processed data.
- *Surveillance radar with remote/local activation/ deactivation device* consists of a modern and small-sized equipment, suitable for identifying other means of transport, such as boats of various types, airplanes, UAVs, etc. capable of carrying out surveillance of an area within a radius of about 40 kilometers.

The radar is capable of activating the following remotely controllable operating modes:

- *Short-distance surveillance mode* - which consists of an omnidirectional exploration with reduced emission power, minimum duration of the transmitted pulse, minimum quantity of pulses, to reduce the probability of being intercepted.
- *Wide-range Sighting Mode* - consists of identifying targets up to the maximum operating distance, determining their direction with good precision both in azimuth and in elevation.
- *Target Aiming and Tracking Modes* - to detect the position of the target and to follow its path. With this function the forecast of the future point of the moving target is carried out.
- *Multiple self-protection functions (ECCM)* - Monopulse mode, Frequency Jumping, Pulse Compression, Sidelobe Suppression, Velocity Gating, etc.
- *Cooperation with the ESM Receiver* - The Goniometric Receiver, equipped with great sensitivity, being always active (without Radio Frequency emission), can transfer the angular data to the Radar in order to refine the determination of the position of the target.

The complete equipment is physically composed of the following sub-assemblies: Active Antenna, Control Unit, Data Display, Digital Data Output Ports. Specifically:

Active Antenna - completely static and completely solid-state is formed by four faces arranged at 90°, each of which constitutes a rectangular array of relatively broadband radiators, capable of electronically scanning the beam.

The Transceiver modules (TxRx), directly coupled to the radiators, provide for

- Provide the power to be transmitted, necessary for correct operation in the desired range.
- Provide reception sensitivity and self-protection from any signals of strong intensity (reflections from large metal masses located a short distance from the antennas, beams from other radars operating nearby, etc.).
- Direct the antenna beam in space (in azimuth and elevation), both in transmission and reception, by appropriately varying the relative phase of each module.
- Taper the beam to optimize the secondary lobes.
- Cooperate for the ECCM.

The Control Unit: is a separate unit from the antenna, which also remotely controls all the Radar controls: Selection of the various Operating Modes (Short-distance Surveillance, Wide-range Sighting, Cooperation with ESM Receiver, Recognition signal emission (LIFF), ECCM Techniques It also provides for all numerical data processing and interfaces with the Active Antenna, with the Data Display and with the Digital Data Output Ports.

Data Display: High resolution graphic display for the visualization of all the transmitted data and for the predisposition of the appropriate actions.

Data Output Ports: for interface data to be provided or received from/for all peripherals.

It should be noted that the buoys mentioned in addition to being characterized by a relatively low cost, do not require periodic maintenance, during their life cycle, of the equipment on board and can be profitably placed at sea. It is understood that they can be recovered, replaced and rescheduled for future missions.

V. Wind Platform

The wind platforms to be dedicated to maritime surveillance are much larger than the buoys, so much so that they can have accommodation for staff, workshops for maintenance and storage of both buoys and other "hardware" dedicated to maritime surveillance.

Figures 8 and 9 show that the "D.P.E. radome" it is equivalent to that embarked on the buoys but the higher position gives the electronic equipment a greater geographical horizon. Furthermore, the generation of energy for operation is redundant, so much so that the excess of overproduction can be programmed to power other non-energy-producing offshore platforms or selected sites on land by means of cables laid on the bottom.

The wind platform, by virtue of its size (Figure 10) acts in all respects as a logistical base, illuminated in the EEZ (and therefore under the jurisdiction of the Coastal State), as well as a site aimed at maritime surveillance tout court.

Furthermore, depending on its structure, it can form a maritime agglomeration as shown in figure 11.

VI. Existing Commercial Platform

The commercial platforms are predominantly petroleum. An oil rig is an impressive structure used for the exploration of marine areas where potential hydrocarbon fields are located. When the existence of a field is identified and proven, the platforms are also used for drilling oil wells. Once the well is finished, the platform can be used to extract hydrocarbons from it, or it can be moved to another location to perform a new drilling.

As described above, the platforms can be essentially classified into two macro-categories:

- Drilling platforms
- Production platforms.

Both categories share the following facilities:

- Heliport, consisting of a platform dedicated to the landing of helicopters and often built in such a way as to be detached from the body of the plant for safety reasons but still properly connected to the body of the plant.

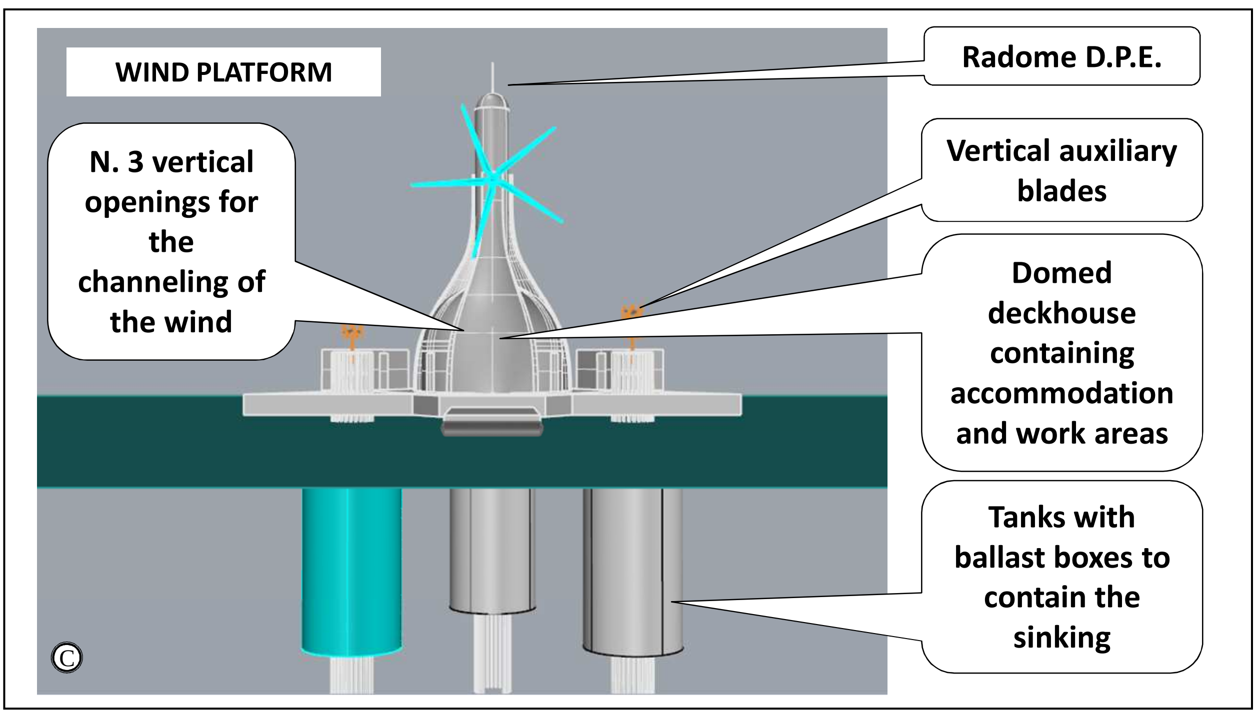

Figure 8: Artistic vision of the wind platform functional to maritime surveillance

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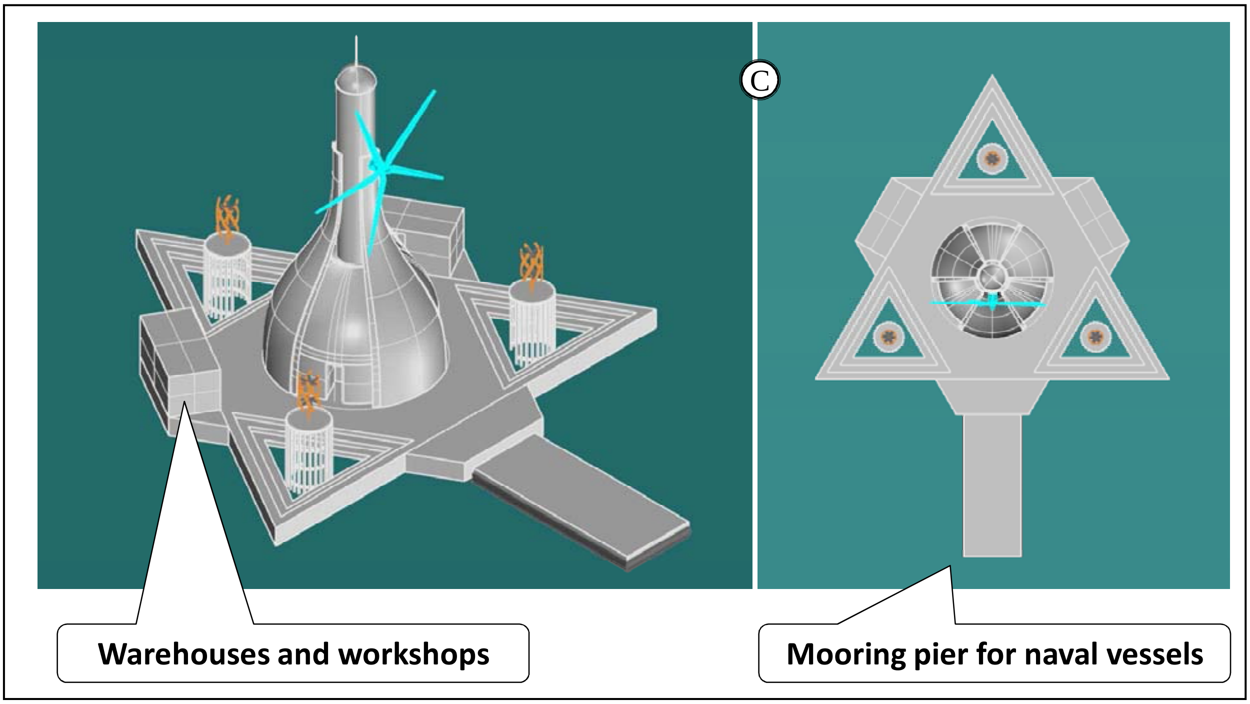

Figure 9: View of the wind platform where the docking capabilities of ships for refuelling or disembarking of personnel and warehouses/workshops are highlighted

- Equipped with special evacuation boats for personnel from the plant in case of emergency
- One or more cranes for loading on board and unloading materials from the support vessels to the platform
- Generating sets for the production of the necessary electricity
- Staff quarters, with canteen, kitchen and recreation room

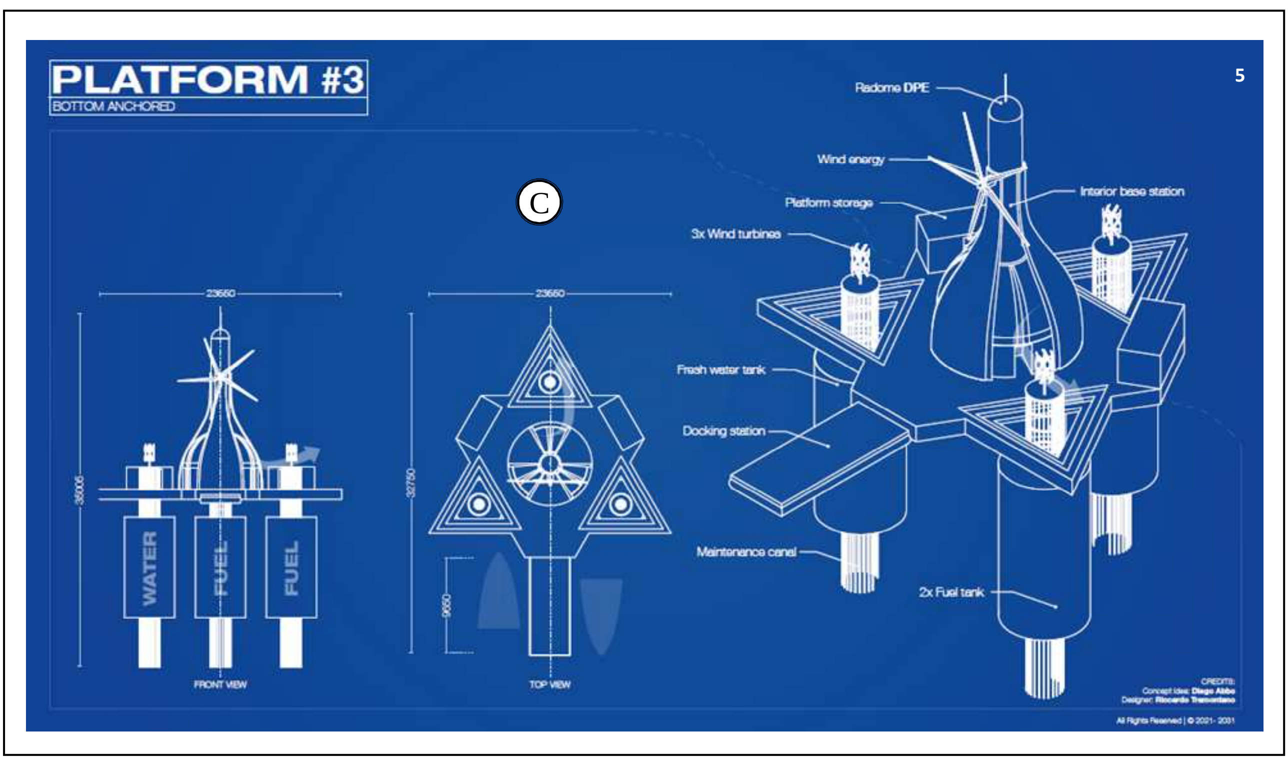

Figure 10: Dimensions of the wind platform

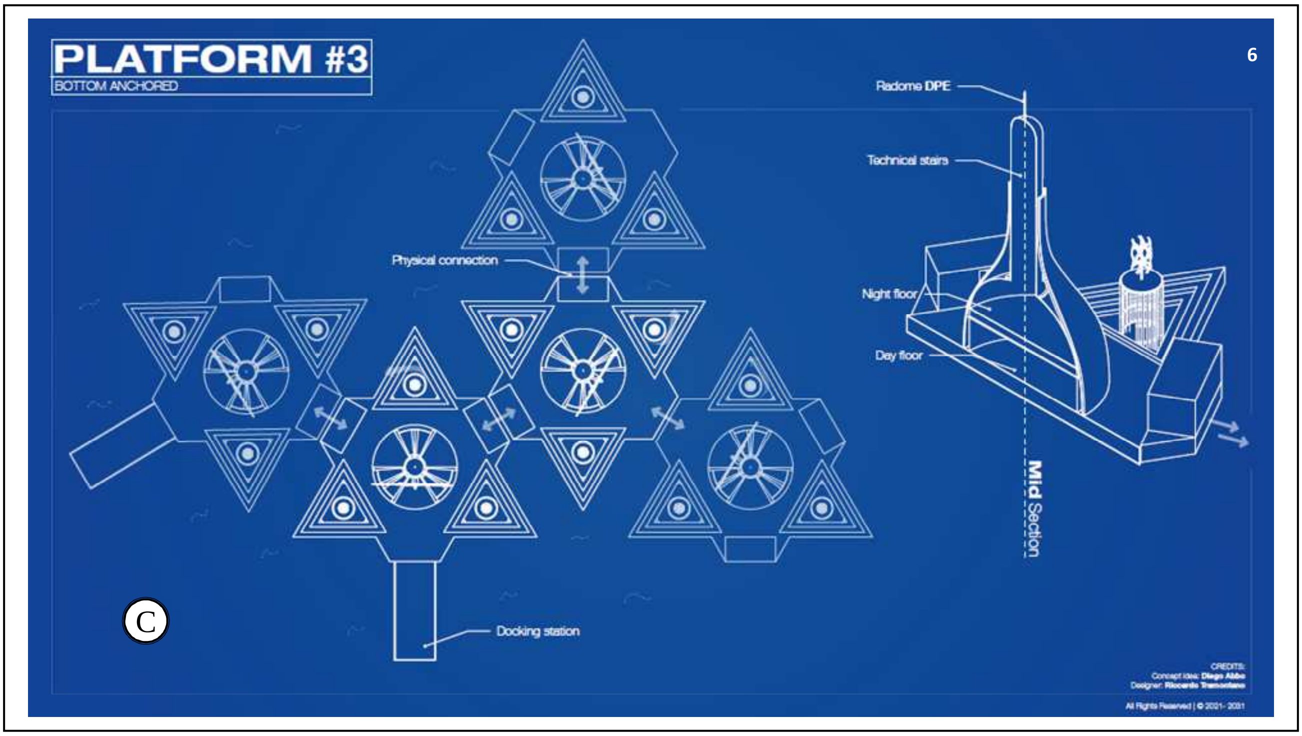

Figure 11: Agglomeration of wind platforms

- Drilling tower: always present in the drilling platforms, it can be absent in the production platforms if they are positioned in a field where the wells have been previously drilled or they can be removed if the development of the field has been completed and no other opportunities are foreseen of their use.
- Blowout preventer, usually abbreviated BOP, to prevent any eruptions of the well on which you are working.

The oil platforms are always manned while the platforms relating to offshore wind turbines can be manned or unmanned.

The sensors to be used would be the same ones mentioned above both for the wind turbines and for the buoys.

VII. Conclusions

The drafting of a maritime surveillance network using the platforms described from scratch or the implementation of the D.P.E. on already existing positions at sea it would increase exponentially the maritime surveillance capacity of any State and therefore of its Naval Power.

In fact, the aforementioned platforms represent, from a secondary use perspective, an effective operational support both with regard to the triangle D.P.E. (Detection, Positioning, Engagement) and with regard to the logistics supply in the area.

Furthermore, they would represent a "Dual use" backbone structure that can fulfill all the following tasks: surveillance for military and maritime police purposes, merchant traffic monitoring, a series of navigation aids and related dangerous situations, detection of flows of fish fauna, constant observation of environmental parameters of interest, measurement of the pollution rate.

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Thermoimpulse as a True Extensive Measure of Heat

By Prof. Valeri Etkin
Togliatti State University

Abstract- The expediency of replacing the Clausius entropy with a more adequate concept of "thermal impulse" as a measure of the amount of disordered motion in the system is substantiated. It is shown that the thermal impulse also exists in nonequilibrium systems, where it can also both increase and decrease. This makes it possible to solve the problem of thermodynamic inequalities, to return the concept of force to thermodynamics, to unify the methods for finding heterogeneous forces, to propose simpler criteria for the equilibrium, evolution and involution of each degree of freedom of the system separately, to substantiate the unity of the laws of transformation of any form of energy, to eliminate the blatant contradiction of thermodynamics with the nature of biological and cosmological evolution, etc. Other advantages of the thermal impulse are also revealed, which facilitate the proof of its existence, its applicability to thermally inhomogeneous media, physical visibility, measurability, ease of eliminating a number of paralogisms of thermodynamics, etc.

Keywords: entropy as a heat transfer coordinate and irreversibility criterion, its generalization to nonequilibrium states, elimination of its paradoxes and easing understanding.

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THERMOIMPULSEASATRUEEXTENSIVEMEASUREOFHEAT

Strictly as per the compliance and regulations of:

Thermoimpulse as a True Extensive Measure of Heat

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I. Introduction

More than 150 years have passed since the concept of entropy and the principle of its increase in irreversible processes entered the natural sciences [1]. However, disputes persist about the hidden meaning of this concept and about the physical foundations of the mentioned principle [2], which led to the loss of the former glory of the theory by thermodynamics, "whose conclusions will never be refuted by anyone [3]. In the extensive scientific and near-scientific literature, hundreds of books and thousands of articles are devoted to it, where these issues are discussed from various points of view [4]. Nevertheless, the inconsistency of the theory of thermal death of the Universe by R. Clausius [2] has not yet been satisfactorily proven, and "the glaring contradiction between thermodynamics and evolution [5] has not been eliminated. Meanwhile, the concept of entropy has crossed the boundaries of physics and penetrated the most intimate areas of human thought. Along with the thermodynamic entropy of R. Clausius, statistical, informational, mathematical, linguistic, intellectual, etc. entropies appeared, which further complicated the interpretation of this many-sided and poorly intuitive concept.

Against this background, tries to replace entropy with a more adequate parameter capable of both increasing and decreasing in evolution and involution remained practically unnoticed [6]. The need for this increased with the application of thermodynamic methods to biological and cosmological systems [5, 7], as well as to the study of the kinetics of various irreversible processes [8]. At the same time, paralogisms like the theory of the heat death of the Universe or the Gibbs paradox have arisen in almost every field of application of thermodynamics [9]. Entropy has become a "scapegoat" for "any and all" irreversibility and the "Achilles' heel" of thermodynamics [10].

One of the aims of this article is to reveal the duality and internal inconsistency of the concept of entropy as a parameter introduced by R. Clausius as the heat transfer coordinate, but, spontaneously increasing in any irreversible processes. Our main goal is to propose another, simpler and more understandable parameter that covers both these cases and cuts all paralogisms associated with entropy.

II. Inadequacy of Entropy as a Coordinate of Heat Transfer

Thermodynamics as one of the fundamental disciplines was formed at a time when, under the pressure of new experimental facts, the idea of heat as an indestructible fluid (caloric) collapsed, and with it, as it seemed then, the theory of heat engines based on its Carnot (1824) [2]. This prompted R. Clausius, the founder of equilibrium thermodynamics, to reconsider the concept of heat as a chaotic form of energy and define it as a quantitative measure of the heat transfer process [1]. The interpretation of heat as "energy in a state of transfer," i.e., a function of a process, at once limited thermodynamics to equilibrium systems and quasi-static (infinitely slow) processes. The fact is that in non-equilibrium systems, the change in entropy is due not only to heat transfer, but also to internal sources of frictional heat, electromagnetic heating, chemical reactions, etc. Such sources made it necessary to consider heat on a par with such phenomena as light, sound, electricity, and magnetism [2]. The understanding of heat as a "hidden" movement of a

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special kind, characterized by randomness, has survived to this day both in the concept of the heat capacity of the system and in the theory of heat transfer, which defines it as a process of exchange between bodies of internal thermal energy (according to the principle: you can only exchange what have both sides). Moreover, such an understanding turned out to be the only one acceptable for the thermodynamics of irreversible processes (TIP) [11, 12], which deals with the above-mentioned internal heat sources.

The replacement of the original concept of heat as a function of a state by heat as a function of a process gave rise to periodically arising discussions. They eventually led to an understanding of the need to distinguish between "body heat" as a quantitative measure of internal thermal energy, and "process heat" as a quantitative measure of heat transfer. In our works, this circumstance is emphasized by the fact that the heat of the body is denoted by U_q, and the heat of the process - by Q, and for infinitesimal increments the first one uses the sign of the total differential dU_q, and for elementary quantities of heat $đQ$ as a function of the process, the sign of the incomplete differential $đ$ due to its depending on the nature of the process [8]. The difference between them is that when the process terminates, the first remains unchanged, while the second vanishes.

The interpretation of heat Q as a quantitative measure of heat transfer required the founders of thermodynamics to find a specific coordinate for this process, i.e., a parameter that necessarily changes during heat transfer and still is unchanged in its absence. To do this, R. Clausius had to confine himself to considering equilibrium systems to exclude the internal sources mentioned above, and to assume the existence of "equilibrium processes". This phrase included two incompatible concepts “equilibrium” and “process”, since equilibrium in thermodynamics is understood as a state characterized by the termination of any macroprocesses [13]. This incompatibility can be verified by representing any extensive parameter of the system Θ_i (its mass M, internal energy U, the number of moles of k-th substances N_k, entropy S, electric charge Q_e, impulse P, its momentum L, etc.) in a continuous medium by the integral of its local density $\rho_i = d\Theta_i/dV$ and average density $\overline{\rho}_i = \Theta_i/V$ by the expression $\Theta_i = \int\rho_i dV = \int \overline{\rho}_i dV$. In this case

$$d\Theta_i/dt=\int [(d\,(\rho_i - \overline{\rho}_i)/dt]\,dV \equiv 0 \qquad (1)$$

According to this identity, in a homogeneous medium, where the difference (ρ_i - $\overline{\rho}_i$) vanishes everywhere, the integral (1) vanishes in the same way, i.e., the value Θ_i stays unchanged. Thus, in homogeneous systems, no processes (including heat transfer) are possible [8]. This means that, assuming the system to be homogeneous (internally balanced), R. Clausius “throws the baby out with the water”, putting an insoluble internal contradiction into his theory. It resulted in the actual transformation of thermodynamics into thermostatics since it forced it to confine itself to infinitely slow ("quasi-static") processes. However, for such processes, the concept of their driving force, which appears in the laws of thermal conductivity, electrical conductivity, diffusion, viscous friction (including the “driving force of heat” by S. Carnot) has lost its relevance due to its infinite smallness. Thus, the concept of force disappeared from thermodynamics, and with it, its ability to explain the cause of the occurrence of processes, reveal their "mechanism", direction, moment of completion, etc. For this, thermodynamics was forced to involve "from outside" physical kinetics, molecular-kinetic and statistical-mechanical theories. The possibility of defining equilibrium as the vanishing of the resultant force has also disappeared, which needed the use of conditions for the extremum of entropy or a series of thermodynamic potentials. This left an imprint on the entire system of substantiation of thermodynamics, including the proofs of the principles of the existence and increase of entropy [14].

One of the founders of thermodynamics, R. Clausius, used for this the theory of cyclic heat engines by S. Carnot (1824) [2]. In it, the thermal efficiency of its ideal cycle $\eta_t^K = 1 - T_2/T_1$ was decided by constant temperatures of the heat source T_1 and heat receiver T_2, and the condition of its maximum was expressed in the requirement of the absence of any decrease in the "driving force of heat" T_1 - T_2, not associated with the performance of work. In this case, representing any cycle as an infinite number of Carnot cycles with elementary quantities of input and output heat $đQ_1$ and $đQ_2$ and expressing its efficiency η_t = 1 - Q_2/Q_1 both in terms of temperatures T_1 and T_2, and through these heats [13], we have:

$$\eta_t = 1 - đQ_2/đQ_1 = \eta_t^K = 1 - T_2/T_1 \qquad (2)$$

Such a proof, as far as we know, has met with no objections so far. Meanwhile, in the same way it was possible to prove the existence of another, more general, extensive measure of the quantity of thermal motion than entropy. If, for example, we consider a heat engine as a device that converts internal thermal energy U_q into work (without replacing it with heat Q as a function of the process), and substitute in (2) instead of Q_1 and Q_2 its quantity at the input and output of the heat engine U_q' and U_q'', we find that $\oint đ(U_q/T) = \oint đP_q = 0$.We will find out the meaning of the parameter P_q later. For now, we note that its existence as a ratio of two parameters U_q and T did not need to be substantiated at all.

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III. Failure to Divide Energy Exchange into Heat and Work

The proof of the existence of entropy by R. Clausius turned out to be inextricably linked with his idea of heat Q and work W as the only two possible ways of energy exchange between the system and the environment. This is reflected in the equation of the first law of equilibrium thermodynamics [13]:

$$đQ = dU + đW \qquad (3)$$

Meanwhile, the transition to the study of open systems exchanging matter with the environment led to the establishment of the fact that, along with heat transfer Q and work W, there are two more types of energy exchange: the boundaries of a system characterized by a change in the composition of the system while its mass stays unchanged. At the same time, it turned out that “at the boundary where diffusion takes place” “the classical concepts of heat and work lose their meaning” [15].

The division of energy exchange into heat transfer and work has become even more problematic in complex (polyvariant) systems, in which, along with expansion work $đW_p = pdV$, other types of work are performed, including a special category of “technical” work $W^т$, which has passed into thermodynamics from mechanics (Л (Carnot, 1783; Poncelet, 1826) [2]. Such work was measured by the scalar product of the vector of the resulting force F and the displacement $d\mathbf{r}$ caused by it of the object of its application $dW^т = \mathbf{F}\cdot d\mathbf{r}$. It was a quantitative measure of the process of transformation of external energy $\mathcal{E}$ from its i-th form $\mathcal{E}_i$ into j-th $\mathcal{E}_j$, which is also a state function. Therefore, such work did not depend on the path of the process, and its elementary amount $dW_i^т$ was expressed by the total differential $dW_i^т = \mathbf{F}_i\cdot d\mathbf{r}_i = d\mathcal{E}_i$. Such work was fundamentally different from the category of work that appeared in equation (3), primarily by the vector nature of the coordinates $\mathbf{r}_i$. This work was performed by external forces and had the meaning of a quantitative measure of the process of energy conversion, and not energy transfer, as the work of introducing a charge, k-th substance or volume (expansion work $đW_p = pdV$). These types of work, performed by internal forces and depending on the path of the process, should be called "non-technical" $đW_i^н$. Misunderstanding of their difference, i.e., the fact that “work is different from work”, still prevents us from realizing that the true “watershed line” does not pass between heat Q and work W, but between technical $dW_i^т$ and non-technical $đW_i^н$ types (categories) of work. Heat transfer should also be included among the latter since it is the work of introducing the amount of chaotic motion. For complex systems that perform both technical and non-technical types of work, there is no proof of the existence of entropy so far [13, 14]. We are not talking about non-equilibrium (spatially inhomogeneous) systems, where, in addition to external heat transfer, there are internal heat sources. Extrapolation of the concept of entropy to such systems continues to multiply the number of paralogisms, turning it into a "cancer" of thermodynamics [9].

It may seem that the severity of this problem can be largely smoothed out by the statistical interpretation of entropy as a measure of the thermodynamic probability of a state [2]. However, it also turned out to be incompatible with the concepts of “entropy flow” and “entropy production”, which are used in nonequilibrium thermodynamics [11,12]. Moreover, no interpretation of entropy can prevent the transition of the joint equation of the 1st and 2nd principles of thermodynamics (3) into the inequality $TdS > dU + pdV$, which made it impossible to calculate energy exchange based on it, both in the framework of nonequilibrium thermodynamics and in other technical disciplines that study real processes.

All this forces us to start “from scratch” and return to the search for a more general parameter that could serve as an extensive measure of the internal thermal energy of the system U_q of any (including open, polyvariant and nonequilibrium) systems.

IV. True Extensive Measure of Internal Thermal Energy

The desire to build a thermodynamic theory that is valid for the general case of open, non-equilibrium, polyvariant and isolated systems dictates the need to build it based on a deductive approach "from the general to the particular". This is exactly what “Thermokinetics” [8] is like as a unified theory of the processes of transfer and transformation of any form of energy, proposed by us in our doctoral dissertation [16]. It is based on the "principle of certainty of energy", according to which the number of arguments of energy as the most general function of the state of the system under study is equal to the number of independent (qualitatively distinct and irreducible to others) processes of its relaxation. This principle is proved by the "theorem on the number of degrees of freedom" of an arbitrary system, according to which the latter is equal to the number of independent (i.e., special, experimentally distinguishable, and irreducible to others) processes occurring in the system. Thus, any arbitrariness in the definition of the concept of energy is eliminated and “underdefinition” or “redefinition” of the system is prevented (i.e., tries to describe its state by a missing or excess number of variables), which is the main reason for the methodological errors of many modern theories [7].

To start "from scratch", let's return to the concept of "momentum" $\mathbf{P} = M\boldsymbol{\upsilon}$ and "manpower" $M\upsilon^2$, introduced by R. Descartes and G. Leibniz [2]. It is easy

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to show that Leibniz's "living force" is the internal energy of the disordered oscillatory motion of the particles that make up the system, regardless of its structure, homogeneity, and composition. Indeed, in an inhomogeneous system, its density $\rho = dM/dV$ becomes a function of spatial coordinates (radius vector r) and time t, i.e., $\rho = \rho\,(r,\,t)$, so that its total time derivative $d\rho/dt$ includes into itself the local $(\partial\rho/\partial t)_r$ and convective $(\partial\rho/\partial r)\,(dr/dt) = (\boldsymbol{\upsilon}\cdot\nabla)\rho$ components:

$$d\rho/dt = \boldsymbol{\upsilon}\cdot(\partial\rho/\partial \mathbf{r}) + (\partial\rho/\partial t)_r \tag{4}$$

This expression is a "kinematic" equation of the first order wave, in which $d\rho/dt$ plays the role of its damping function [17]. It describes a wave propagating from a source, which is illustrated in Figure 1. According to this figure, a traveling wave is generated by the transfer of a certain amount M of matter from a position with a radius vector r' to a position r. The average velocity υ of this transfer is decided by the displacement ratio r''- r' to the period of the wave ν^{-1} with frequency ν and is obviously equal to the propagation velocity of perturbations in the given medium. The modulus of this speed in any substance υ is related to the speed of light in a vacuum with a refractive index $n = c/\upsilon$, which gives the "living force" the meaning of the energy of the internal oscillatory motion of the system (its internal thermal energy U_q):

$$U_q = M\upsilon^2 = n^{-2}Mc^2 \tag{5}$$

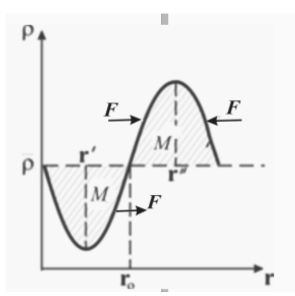

Figure 1: Wave formation

This expression corresponds to the principle of equivalence of the energy E_o and rest mass M_o of A. Einstein, if we take the speed of light in the void as maximum ($n_o = 1$) and consider the identity for stationary systems M and M_o, as well as U_o and E_o. According to him, the internal thermal energy of a substance U_q is expressed as the product of extensive and intensive measures of motion, which are the amount of motion $P = M\upsilon$ and the average speed of oscillatory motion υ. Thus, the energy carrier of the chaotic form of motion in the U_q system is the scalar momentum $\Theta_q \equiv P_q = M\upsilon$, which we called for brevity the thermoimpulse (i.e., the impulse $\boldsymbol{P} = M\boldsymbol{\upsilon}$, which has lost its vector nature due to the chaotic motion). It becomes possible to replace the entropy S with this simple and intuitive parameter. The substantiation of the expediency of this will be the subject of the later part of this article.

V. The Need to Replace Entropy with a Thermoimpulse

In the extensive literature on entropy, tries to revise and generalize the basic concepts of thermodynamics are extremely rare. This can be explained by the extremely painful feeling of such attempts on the part of specialists and individuals who avoid at least a temporary loss of such a recognized support. As a result, errors accumulate, and it becomes more and more difficult to find the origins of apparently absurd conclusions.

An approach to this problem from the standpoint of the "certainty principle" reveals that R. Clausius from the very beginning went on the wrong path, leading away from the theory of heat engines of S. Carnot. This theory explicitly pointed to the temperature difference ΔT between the heat source and the heat sink as a condition for the emergence of a "heat driving force", and any decrease in it, not related to the performance of work, as the reason for a decrease in the efficiency of a heat engine [2]. This theory for the first time revealed the independence of the efficiency of an ideal cycle from the nature of the working fluid and showed ways to increase it, which were fully realized in the future in thermal power engineering. It was enough just to part with the idea of caloric as a weightless and indestructible liquid and consider it as a carrier of a special kind of motion, distinguished by its randomness. However, R. Clausius went the other way, replacing the quantitative measure of the carrier of internal thermal energy U_q with a quantitative measure of the heat transfer process Q, which made the entropy S a "scapegoat" for "any and every" irreversibility.

This was most clearly manifested in the entropy balance equation written by I. Prigogine in the form [18]:

$$dS = d_eS + d_uS \tag{6}$$

where $d_eS = đ_eQ/T$ and и $d_uS = đ_uQ/T$ are the parts of the entropy change due to heat transfer $đ_eQ$ and internal heat sources $đ_uQ$, respectively.

Note that d_eS and d_uS are not partial differentials of entropy, which takes (6) out of the scope of the theory of differential calculus. However, it is even more important that any irreversible processes in it cause a change in the same parameter - the entropy S. Other parameters also have internal sources or sinks. Such are the numbers of moles of k-x substances N_k, which also change both because of chemical reactions and during diffusion of k-x substances through the boundaries of the system.

Further, according to (6), the entropy S increases only because of the transformation of ordered forms of motion into chaotic ones. However dissipation is accompanied by the transition of energy into potential energy. In cutting metals, it was found that the ratio of the amount of dissipation heat released Q^d to the work expended W^T, called the "heat output coefficient", is usually less than one. This means that part of the work of destruction of metals is converted into the potential energy of the chips, and not into heat. This circumstance manifests itself even more clearly in crushing materials, in which not only the temperature increases, but also the surface energy of the particles of the material. Thus, experience confirms that the increase in entropy is by no means the only consequence of the transformation of ordered forms into disordered ones.

Moreover, it turned out that thermal energy, already considered chaotic, can also be dissipated. Direct experimental confirmation of this circumstance was a series of experiments by L. Brovkin (1960, 1964) [18]. In them, in the gap of a densely packed roll of paper, cardboard, rubber tape and other sheet materials, along their entire length, a sensitive element of a resistance thermometer was laid. Then the roll was subjected to uneven heating from an external heat source, and in the later process of its cooling, a change in the resistance of such a "dispersed" thermometer, which characterizes the average integral temperature of such a system, was recorded.

The most surprising result of these experiments was a rather significant (up to 17%) rise in temperature during the first period of the roll relaxation process instead of the expected decrease. It continued for tens of minutes until the cooling of the sample began to predominate. This phenomenon, called by the author "the effect of the growth of the measured heat content", has not yet been satisfactorily explained. It becomes understandable only from the standpoint of nonequilibrium thermodynamics, which recognizes the existence of an ordered (potential) part of the internal energy of a thermally inhomogeneous system. Due to this ordered part of the internal thermal energy of the environment, heat engines do the work, and in this case, its kinetic part increases.

The fact that such relaxation processes do not contradict the principles of conservation and transformation of energy can be seen by being the "living force" as the result of the mutual transformation of ordered and disordered forms of energy:

$$dU_q \equiv dM\upsilon^2 = d(M\boldsymbol{\upsilon}^2/2) + \boldsymbol{F}\cdot d\boldsymbol{r} = dE^\upsilon + dE^r \qquad (7)$$

where $E^\upsilon = M\boldsymbol{\upsilon}^2/2$, $E^r = \int \boldsymbol{F} d\boldsymbol{r} = \int \boldsymbol{\upsilon} \cdot d\boldsymbol{P}$ are the kinetic and potential energies of the system.

According to this expression, the ordered forms of energy E^υ and E^r of an isolated system such as the Universe are in sum equivalent in size to its internal vibrational energy U_q and, upon dissipation, can pass into it to the same extent as it does when it passes into ordered forms because of self-organization or as the vibrations decay. In other words, the law of conservation of energy does not exclude the circulation of energy forms due to the interconversion of the material and field forms of matter in the Universe. On the contrary, the transition of a part of the potential energy of the field form of the matter of an inhomogeneous Universe into the kinetic energy of ordered E^υ and disordered U_q motion, and the latter into the potential energy of "inhibited" motion, is a manifestation of the laws of dialectics. It allows us to give energy the sense of a common measure of all forms of motion.

In this case, the representation of the "live force" in the form of the product of the thermoimpulse $P = M\upsilon$ by the modulus of its average velocity υ allows us to give them the meaning of an extensive and intensive measure of internal thermal energy U_q, respectively. In this case, the thermoimpulse P_q will appear as a quantitative measure of the carrier of a given form of energy (briefly: energy carrier), and its potential $\psi_q \equiv \upsilon$ – a measure of the intensity of movement. If, in this case, one does not resort to the molecular-kinetic theory, but relies only on experience, then it is quite natural to consider ψ_q as a measure of temperature T, and the momentum of one particle (molecule) $p = P/N$ as gas pressure. Since the number N of particles in the volume of one mole of gas $V_\mu = 22{,}4$ m^3/kmol is equal to the Avogadro number $N_A = 6{,}022169 \cdot 10^{26}$, then, taking atmospheric pressure $\boldsymbol{p} = 101{,}325$ kPa and temperature $\boldsymbol{T} = 273{,}15$ K as normal conditions, directly we come to the equation of state of an ideal gas $\boldsymbol{p}V_\mu = R_\mu \boldsymbol{T}$, in which the universal gas constant R_μ has the same value of 8314 J mol^{-1} K^{-1}. By this representation, the absolute temperature T should be measured not in Kelvins, but in m/s, so that the vibrational energy $U_q = PT$ is expressed in J. potentials ψ_i - the meaning and dimension of the speed of the corresponding form of motion. This would mean a genuine revolution in the system of physical quantities, radically reducing the number of concepts and easing not only the transition from one discipline to another, but also the understanding of the physical essence of such energy carriers as an electric charge.

Another advantage of the thermal pulse is its ability both to increase in heat transfer, mass transfer and diffusion or during energy dissipation, and to decrease during damping of oscillations or during the transformation of disordered forms of motion into ordered ones. An example of such processes is the spontaneous evolution saw at all levels of the universe - from nucleosynthesis to the formation of stars and clusters of galaxies.

Replacing the entropy with a thermal pulse makes it possible to cut the incorrectness of expression (6). The total differential $dU_q = d(\boldsymbol{PT})$ should be represented as the sum of two terms:

$$dU_q = TdP + PdT \qquad (8)$$

Let us compare this expression with the total differential of the internal energy density $\rho_q = dU_q/dV$ as a function of the radius vector $\boldsymbol{r}$ of the temperature field and time t, which includes the convective $(\boldsymbol{\upsilon}\cdot\nabla)\rho_q$ and local $(\partial\rho_q/\partial t)_r$ components:

$$d\rho_q/dt = (\boldsymbol{\upsilon}\cdot\nabla)\rho_q + (\partial\rho_q/\partial t)_r \qquad (9)$$

The first term on the right side of (9) decides the flow of thermal energy U_q through the boundaries of the system (which for the system corresponds to the heat exchange $đ_eQ/dt$), the second term determines the internal heat sources $đ_uQ/dt$. Thus, in nonequilibrium systems, heat transfer can also be expressed through a change in the parameters of the system $đ_eQ = TdP$ without the occurrence of thermodynamic inequalities [20].

It stays to be shown that the replacement of entropy by the thermoimpulse makes it possible to cut several other paralogisms that have arisen in thermodynamics when trying to use entropy as an extensive measure of thermal motion [9].

VI. What does the Replacement of Entropy with a Thermoimpulse give?

Thermoimpulse as an extensive measure of thermal motion has obvious advantages. This parameter does not require proof of its existence and has the degree of evidence that satisfies the concept of a phenomenological theory. It frees from the need to justify the applicability of the concept of entropy to systems far from equilibrium, since it also exists in systems with an arbitrary distribution of momentum between particles. This parameter specifies the meaning of the absolute temperature T as a measure of the intensity of thermal motion, equal to the average velocity υ of the disordered oscillatory motion of the particles that form the system. Understanding the thermoimpulse as a quantity of an oscillatory form of motion allows us to return to energy its original meaning of the most general measure of all forms of motion of matter and thereby put an end to the situation when "modern physics does not know what energy is" [21]. Finally, this parameter does not require the involvement of molecular-kinetic and statistical-mechanical theory to interpret its physical meaning of thermodynamic parameters, which makes it a completely self-sufficient theory. Below we consider the most important consequences of such a replacement.

a) *Elimination of Inequalities in the Mathematical Apparatus of Thermodynamics*

It is known that the joint equation of the 1st and 2nd laws of thermodynamics in the case of irreversible processes takes the form of inequality [2,13]:

$$TdS > dU + pdV \qquad (10)$$

The reason for the appearance of inequalities is that in the absence of equilibrium, internal heat sources appear in the system, because of which $TdS > đQ$. Similar inequalities arise for other parameters Θ_i, including its volume V, which can increase when the system expands into the void without performing work $đW_p{}^{н} = pdV$. This circumstance is the main obstacle to the application of the thermodynamic research method to other disciplines that study real (non-static) processes.

Meanwhile, another approach to the derivation of the basic equation of thermodynamics is possible, based on the representation of the internal energy of the system U as a function of the quantities of motion of various kinds $\boldsymbol{P}_i$ (including the thermoimpulse $\boldsymbol{P}_q$). In this case, the energy of the system $U = \Sigma_i U_i(\boldsymbol{P}_i)$, and its total differential can be represented as an identity [8]:

$$dU \equiv \Sigma_i \Psi_i dP_i \qquad (11)$$

where $\Psi_i \equiv (\partial U/\partial \boldsymbol{P}_i)$ is the mean integral value of the generalized potential (absolute temperature T and pressure p, chemical μ_k, electric ϕ, gravitational ψ_g, etc. potentials).

As we can see, inequalities do not arise if we pass from the entropy S and other coordinates of the energy exchange processes Θ_i to the quantities of motion $\boldsymbol{P}_i$ of the corresponding degrees of freedom of the system, considering the internal sources of partial energy U_i. An equally important advantage of such a replacement is the possibility to introduce into thermodynamics the concept of a scalar (internal) thermodynamic force F_i as a derivative of the momentum of a given kind $\boldsymbol{P}_i$ with respect to time $F_i = dP_i/dt$. These forces buy a vector character with an uneven distribution of the density $\rho_i(\boldsymbol{r}, t) = d\boldsymbol{P}_i/dV$ of the momentum $\boldsymbol{P}_i$ over the volume of the system V, which is accompanied by a shift in the position of its center $\boldsymbol{r}_i$ from the first $\boldsymbol{r}_{io}$ corresponding to a homogeneous state with a density $\rho_{io}(t) = P_i/V$. The position of this center in the current and homogeneous state is decided by the well-known expressions:

$$\boldsymbol{r}_i = P_i^{-1}\int\rho_i(\boldsymbol{r},t)\,\boldsymbol{r}dV;\ \boldsymbol{r}_{io} = P_i^{-1}\int\rho_{io}(t)\boldsymbol{r}dV \qquad (12)$$

where $\boldsymbol{r}$ is the running (Eulerian) spatial coordinate; t - time.

It follows from this that the redistribution of the energy carrier $\boldsymbol{P}_i$ when the system deviates from a homogeneous ("internal equilibrium") state is accompanied by the appearance of a certain "moment of distribution" of the momentum.

$$\boldsymbol{Z}_i = P_i(\boldsymbol{r}_i - \boldsymbol{r}_{io}) = \int[\rho_i(\boldsymbol{r}, t) - \rho_{io}(t)]\,\boldsymbol{r}dV \qquad (13)$$

with the shoulder $\Delta\boldsymbol{r}_i = \boldsymbol{r}_i - \boldsymbol{r}_{io}$, which we called the "displacement vector" [8].

The parameters $\boldsymbol{Z}_i$ have the meaning of the polarization vectors of the system in the most general

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sense of this term as the creation of its spatial inhomogeneity. The appearance of any i-th energy carrier P_i of the distribution moment Z_i with a shoulder Δr_i makes its energy U_i a function of two variables P_i and r_i (at $r_{io}=0$), i.e., $U_i = U_i(P_i, r_i)$. In this case, $U = \Sigma_i U_i (P_i, r_i)$, and its total differential can be represented as an identity [8]:

$$dU = \Sigma_i dU_i \equiv \Sigma_i \Psi_i dP_i + \Sigma_i \boldsymbol{F}_i \cdot d\boldsymbol{r}_i \qquad (14)$$

where $F_i \equiv (\partial U_i/\partial r_i)$ are the forces characterizing the inhomogeneity of the P_i field.

It follows that any force fields $F_i(r_i)$ *arise due to the uneven distribution of the energy carrier* $P_i(r_i)$ *in space*. In this case, the forces $F_i(r_i)$ buy a completely unambiguous meaning of the gradients of the corresponding energy form U_i. This puts an end to lengthy discussions about the origin of force fields, their materiality, the diversity of their nature, the "mechanism" of interaction (contact or exchange), its strength or weakness.

According to (14), the rate of change in the energy of the system can also be represented as the identity

$$dU/dt = \Sigma_i \Psi_i dP_i/dt + \Sigma_i \boldsymbol{F}_i \cdot \boldsymbol{v}_i, \text{ (Вт)} \qquad (15)$$

Velocity $\boldsymbol{v}_i$ can be decomposed into translational $\boldsymbol{w}_i$ and rotational part $\boldsymbol{\omega}_i \times \mathcal{R}_i$ (with angular velocity $\boldsymbol{\omega}_i$ and instantaneous radius $\mathcal{R}_i$). Then we finally get:

$$dU/dt = \Sigma_i \Psi_i dP_i/dt + \Sigma_i \boldsymbol{F}_i \cdot \boldsymbol{w}_i + \Sigma_i \mathcal{M}_i \cdot \boldsymbol{\omega}_i \qquad (16)$$

where $\mathcal{M}_i = \boldsymbol{F}_i \times \mathcal{R}_i$ is the torque of forces F_i.

The three components of the right side of this expression are associated with a change in the momentum of the oscillatory P_i^v, translational $\boldsymbol{P}_i^w$ and rotational $\boldsymbol{P}_i^\omega$, respectively. Its main advantage is that it describes the processes in the system, without dividing them into an infinite number of elementary volumes dV or particles of mass dM. This makes the number of degrees of freedom of the system finite ($i = 1, 2, \ldots I$) and equal to $I = 3K\Lambda$, where K is the number of system components ($k = 1, 2 \ldots K$), Λ is the number of their phases ($\lambda = 1, 2 \ldots \Lambda$). Due to this, identity (16) describes systems with any finite set of properties, while applying to both continuum and corpuscular models. Thus, the synthesis of thermodynamics with other fundamental disciplines is carried out.

b) Disambiguation of the Meaning of the Driving Forces and Speeds of various Processes

In 1931, the future Nobel laureate L. Onsager proposed a "quasi-thermodynamic" theory of the rate of irreversible physical and chemical processes [11]. The main quantities used by this theory were scalar ("thermodynamic") forces X_i as the causes of the i-th scalar relaxation process, and "flows" J_i as their generalized velocities. These quantities were found based on the expression for the rate of entropy occurrence dS/dt as a function of certain parameters α_i characterizing the removal of such systems from equilibrium:

$$dS/dt = \Sigma_i (\partial S/\partial \alpha_i)\, d\alpha_i/dt = \Sigma_i X_i J_i \qquad (17)$$

Finding driving forces $X_i = \partial S/\partial \alpha_i$ and generalized velocities $J_i = d\alpha_i/dt$ of various dissipative processes makes it possible, in principle, to study the kinetics of relaxation processes using thermodynamic methods. The latter would mean a transition from thermostatics, which was classical thermodynamics [12], to thermokinetics as a theory of the rate of real processes [11]. However, the parameters α_i were obviously absent in equilibrium thermodynamics. Therefore, his theory remained essentially an empty formalism until another future Nobel laureate, I. Prigogine, proposed a method for finding vector thermodynamic forces $\boldsymbol{X}_i$ and flows $\boldsymbol{J}_i$ for "stationary" irreversible processes [18]. To do this, he put forward the hypothesis of local equilibrium, according to which there is an equilibrium in the volume elements of the continuum dV (despite the occurrence of non-static processes in them), so that their state is characterized by the same set of variables Θ_i as in equilibrium (despite the appearance of additional thermodynamic forces Xi), and all relations of equilibrium thermodynamics are applicable to them (despite their inevitable transition to inequalities).

For all its internal inconsistency, this hypothesis made it possible to apply the laws of conservation of mass, momentum, charge, and energy, taken from other disciplines, to find the forces $\boldsymbol{X}_i$ and flows $\boldsymbol{J}_i$. This required compiling rather cumbersome equations of their balance to extract from dS/dt that part d_uS/dt that characterizes the "production" of entropy due to dissipation. However, the "entropy production" d_uS/dt, like expression (17), can be decomposed into factors $\boldsymbol{X}_i$ and $\boldsymbol{J}_i$ in many ways. This led to a certain arbitrariness in their meaning and dimension.

An even more serious shortcoming of the theory of irreversible processes (TIP), based on the principle of increasing entropy, was that it excluded from consideration the reversible part of real processes, which does not contribute to the "production" of the entropy dS/dt. This led to the limitation of TIP to purely dissipative processes such as thermal conductivity, electrical conductivity, diffusion, and viscous friction, while thermodynamics was created as a theory of the transformation of various forms of energy with minimal losses from irreversibility.

Identity (16) frees from these shortcomings. Being written in the form

$$dU/dt \equiv \Sigma_i \Psi_i dP_i/dt + \Sigma_i \boldsymbol{X}_i \cdot \boldsymbol{J}_i \qquad (18)$$

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where the thermodynamic forces $X_i \equiv (dU_i/dZ_i) = \Theta_i^{-1}(\partial U/\partial r_i) = F_i/P_i$ have a well-defined meaning of the specific forces F_i in their general physical understanding, it frees from the need to involve other disciplines for their finding and compiling on rather cumbersome entropy balance equations [9, 10]. Thus, it allows generalizing the conceptual system and mathematical apparatus of several engineering disciplines, drastically easing the transition from one of them to others [20].

c) Refutation of the Theory of "Heat Death of the Universe"

R. Clausius, when substantiating the principle of increasing entropy based on the famous argument about the operation of two conjugate heat engines, takes for granted that the thermal efficiency $\eta_t = 1 - Q_2/Q_1$ of any irreversible heat engine is less than in the reversible Carnot cycle $\eta_t^K = 1 - T_2/T_1$ at the same temperatures of heat source T_1 and heat receiver T_2 [13]. In this case, $dS_2 = đQ_2/T_2 > dS_1 = đQ_1/T_1$, i.e., the entropy of the system, which includes a heat source, a cyclically operating heat engine and a heat sink, increases.

Not finding any contradictions in this reasoning, R. Clausius gave this conclusion the status of a general physical "principle of entropy increase" and put it at the basis of the "theory of heat death of the Universe". This theory predicted the termination of any macroprocesses in the Universe due to the onset of thermodynamic equilibrium in it, which was tantamount to the assertion of its "creativity". Thus, this theory still serves as the basis for the standard cosmological model of the origin of the Universe through the "Big Bang", even though the mentioned "heat death" did not occur even after 14 billion years of its existence following this model [2].

Meanwhile, an error crept into Clausius's reasoning, which will become more obvious if we represent the thermal efficiency of any cycle of a heat engine, including the Carnot cycle, through the so-called "average integral" temperatures of heat supply and removal $\overline{T}_1 = Q_1/\Delta S_1$ and $\overline{T}_2 = Q_2/\Delta S_2$ [20]:

$$\eta_t = 1 - Q_2/Q_1 = 1 - \overline{T}_2/\overline{T}_1 \qquad (19)$$

According to this expression, a decrease in thermal efficiency is inevitably associated with a change in the average temperatures of heat supply and removal $\overline{T}_1$ and $\overline{T}_2$, i.e., with a decrease in the "driving force of heat" $\overline{T}_1 - \overline{T}_2$, as it followed from S. Carnot's theory. This means that the very first assumption of R. Clausius that the irreversible cycle at the same temperatures T_1, and T_2 as in the reversible Carnot cycle will have a lower efficiency $\eta_t < \eta_t^K$ is invalid.

Other proofs of this principle turn out to be just as untenable [23]. That is why "the question of the physical foundations of the law of monotonic increase in entropy remains ... open" [24]. The cardinal solution to this issue comes with finding the thermoimpulse P_q as a true measure of internal thermal energy $U_q = TP_q$. According to this expression, the thermoimpulse of the system can both increase and decrease by the value of the internal thermal energy U_q. In this case, the thermoimpulse degenerates not only when the oscillations are damped and U_q is converted into the internal (intrinsic) potential energy of the same system E^r, but also when it is converted into the kinetic energy of the ordered motion E^υ. Indeed, as the speed of the system approaches the limiting speed of light, when the deviation of the speed υ up or down from it vanishes, the oscillatory motion in matter also degenerates. It is for this reason that the temperature T of the physical vacuum, like any other media free of matter, is equal to zero. From this it follows that the thermoimpulse degenerates during the explosion of "supernovae", accompanied by the so-called "big gap", i.e., the transformation of matter into radiation. This process can serve as an example of the emergence of "order" from "chaos", the possibility of which was substantiated by I. Prigogine [5]. Thus, the replacement of entropy by a thermoimpulse cuts the one-sided orientation of processes in the Universe imposed by Clausius thermodynamics, allowing for the possibility of its functioning unlimited in time and space, bypassing the state of equilibrium.

d) Elimination of the Contradiction between Thermodynamics and the Theory of Evolution

Let us now show that the thermoimpulse eliminates "the blatant contradiction of thermodynamics with the theory of biological evolution", since the principle of increasing entropy prescribes only its degradation to nature [25]. Boltzmann's probabilistic interpretation of entropy did not resolve this contradiction since it gave the Universe only an insignificant chance to avoid "heat death". Meanwhile, identity (16), like (1), asserts the deterministic nature of processes in nonequilibrium systems. It follows from (1) that in systems where some processes take place, i.e., $d(\rho_i - \overline{\rho}_i)/dt \neq 0$), integral (1) vanishes only when its terms have the opposite sign and mutually compensate. This means that in any nonequilibrium system there are always subsystems in which processes try in the opposite direction. This provision, which we called the "principle of opposite direction" of processes, has a general physical status, and can be considered a mathematical expression of the dialectical law of "unity and struggle of opposites" [24]. It cuts the one-sided orientation of processes in the Universe imposed by Clausius thermodynamics. We come to the same conclusion based on the law of conservation of energy in an isolated system (dU/dt) from =0 and identity (15), if we stand for $F_i{\cdot}\boldsymbol{\upsilon}_i$ as a product $\boldsymbol{X}_i{\cdot}\boldsymbol{J}_i$, as is customary in nonequilibrium thermodynamics [10, 12]:

$$(dU/dt)_{\text{is}} = \Sigma_i dU_i/dt = \Sigma_i(\Psi_i dP_i/dt + \boldsymbol{X}_i{\cdot}\boldsymbol{J}_{i)} = 0 \qquad (20)$$

where $X_i \equiv (dU_i/dZ_i) = \Theta_i^{-1}(\partial U/\partial r_i) = F_i/P_i; J_i = P_i\boldsymbol{\upsilon}_i$.

The vanishing of the sum $\Sigma_i dU_i/dt$ means that the individual terms of this sum have the opposite sign and cancel each other out. Since in isolated systems the acceleration of movement dP_i/dt is due solely to the presence of internal sources in P_i, the powers $\boldsymbol{X}_i{\cdot}\boldsymbol{J}_i$ of opposite processes of energy conversion have the opposite sign. This means that along with dissipation processes in which $\boldsymbol{X}_i{\cdot}\boldsymbol{J}_i>0$, processes of "self-organization" of some j-th degrees of freedom are inevitable in isolated systems, in which the product $\boldsymbol{X}_i{\cdot}\boldsymbol{J}_i<0$. Such are the processes of "ascending diffusion" (transfer of a substance in the direction of increasing its concentration), the phenomenon of "coupling" of chemical reactions (the course of reactions in the direction of increasing its affinity), "active transport" (accumulation in organs of substances with a higher Gibbs energy), etc. Thus, in non-equilibrium systems, counter-directional processes of evolution and involution (degradation) necessarily arise, when one degree of freedom of the system approaches equilibrium, while the other moves away from it. This drops the above contradiction between thermodynamics and evolution [5].

Moreover, identity (15) also holds parameters Z_i, which reflect not only the approach or removal of the system from the equilibrium state for any i-th degree of its freedom separately, but also the equilibrium condition of this kind [26]:

$$d\boldsymbol{Z}_i, >0 \text{ (evolution)}; \ d\boldsymbol{Z}_i, =0 \text{ (equilibrium)}; \ d\boldsymbol{Z}_i, <0 \text{ (involution)} \qquad (21)$$

Thus, the polarization vectors themselves become more visual and more informative criteria than entropy, which can reflect only the behavior of the system, and, moreover, only its degradation. No less convenient in this role can be thermodynamic forces expressed by potential gradients ($\boldsymbol{X}_i = \nabla\psi_i$):

$$d\boldsymbol{X}_i > 0 \text{ (эволюция)}; \ d\boldsymbol{X}_i = 0 \text{ (равновесие)}; \ d\boldsymbol{X}_i < 0 \text{ (инволюция)} \qquad (22)$$

Thus, thermokinetics returns to the concept of equilibrium its original meaning of the equality of opposing forces (their absence of the resulting force), as it was in mechanics. This gives researchers a more visual, more "physical" and more informative tool for analyzing evolutionary problems than the uncalculable entropy maximum [27]. Non-entropic criteria confirm that nature is characterized not only by destructive, but also by creative tendencies, which are clearly manifested in evolution of animate and inanimate nature occurring at all levels of the universe.

VII. Conclusion

1. The need to search for an alternative to the concept of entropy is due to the blatant contradiction of its consequences to the observed nature of processes in the Universe and the fact of the evolution of biological systems. This deprived thermodynamics of the status of a theory based on experience, and with its further generalization to open, polyvariant and inhomogeneous systems, it led to several paralogisms that made entropy a "cancerous tumor" of thermodynamics.
2. The reason for the inconsistency of the concept of entropy with the essence of the matter is the mistaken division by R. Clausius of the energy exchange of the system with the environment into heat and work, which became obvious only with the transition to the study of open and polyvariant systems. Then it was discovered that the true "watershed line" runs between technical and non-technical types of work as quantitative measures of fundamentally different processes of energy conversion and energy transfer.
3. The replacement by R. Clausius of the concept of "body heat" as a quantitative measure of its internal thermal energy U_q with the concept of "process heat" Q as a quantitative measure of the heat transfer process limited thermodynamics to consideration of equilibrium systems and reversible processes that do not have internal heat sources. Thus, thermodynamics, barely born, turned into thermostatic, which studies only quasi-static processes.
4. The substitution of the empirical principles of the excluded perpetual motion by the law of entropy increase and led to mistaken conclusions about the transition of thermodynamic equations for real processes into inequalities, about the inevitable "thermal death" of the Universe and to a blatant contradiction of thermodynamics with the theory of biological evolution.
5. The proof by R. Clausius of the principle of entropy increase turns out to be contrary not only to the theory of heat engines by S. Carnot, but also to his own conclusion about the equality of entropy changes in cyclic processes of heat supply and removal. The use of this mistaken principle, which has not yet been rigorously proven, has made entropy a "scapegoat" for "any and all" irreversibility.
6. Replacing entropy with a "thermoimpulse" as an impulse that has lost its vector nature due to the chaotic nature of thermal motion, removes the limitations associated with it in the scope of

applicability of thermodynamics, cuts several paralogisms generated by it, and allows us to propose more illustrative and informative criteria for the evolution and balance of living and non-living systems.

7. The use of impulses of the translational, rotational and oscillatory motion of the system as universal carriers of energy of any substance in any of its phase states allows you to return the energy to its simple and clear meaning of the common measure of all (ordered and disordered, translational, rotational and oscillatory) forms of motion and radically simplifies the system of physical quantities, facilitating the transition from one of them to the other.
8. The introduction of the missing parameters of spatial inhomogeneity removes the limitation of the sphere of applicability of TIP by dissipative processes and systems near equilibrium and makes it possible to give the energy conservation law the form of an identity, which is also valid for irreversible processes.
9. Thermodynamic identity cuts arbitrariness in the choice of thermodynamic forces and flows and predicts the emergence of processes in non-equilibrium systems directed "against equilibrium", which causes the simultaneous flow of evolution and involution (degradation) processes in them.
10. Thermokinetics as an entropy-free theory of the rate of real processes of energy transfer and transformation cuts the above-mentioned contradictions of classical thermodynamics and substantiates the possibility of the functioning of the Universe unlimited by time and space, bypassing the state of equilibrium.

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Layer-wise Security Challenges and a Secure Architectural Solution for Internet of Things at Physical, Network and Application Layers

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Abstract- In recent years, the Internet of Things has emerged as one of the most important technologies of the twenty-first century. We can now connect everyday objects to the internet via embedded devices such as kitchen appliances, cars, thermostats, and baby monitors, allowing for seamless communication between people, processes, and things. Because of low-cost computing, the cloud, big data, analytics, and mobile technologies, physical things can share and collect data with minimal human intervention. In this hyper-connected world, digital systems can record, monitor, and adjust every interaction between connected things. The physical and digital worlds intersect and work together. By enabling connected cars, IoT is reinventing the automobile.

Keywords: internet of things (IoT), smart internet of things (SIoT); secure architecture design, secure design, secure engineering, unified secure architecture solution for IoT, connected cars.

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LAYERWISESECURITYCHALLENGESANDASECUREARCHITECTURALSOLUTIONFORINTERNETOFTHINGSATPHYSICALNETWORKANDAPPLICATIONLAYERS

Strictly as per the compliance and regulations of:

Layer-wise Security Challenges and a Secure Architectural Solution for Internet of Things at Physical, Network and Application Layers

Sriranga Narasimha Gandhi Aryavalli [α] & Hemantha Kumar [σ]

Abstract- In recent years, the Internet of Things has emerged as one of the most important technologies of the twenty-first century. We can now connect everyday objects to the internet via embedded devices such as kitchen appliances, cars, thermostats, and baby monitors, allowing for seamless communication between people, processes, and things. Because of low-cost computing, the cloud, big data, analytics, and mobile technologies, physical things can share and collect data with minimal human intervention. In this hyper-connected world, digital systems can record, monitor, and adjust every interaction between connected things. The physical and digital worlds intersect and work together. By enabling connected cars, IoT is reinventing the automobile. The global market for connected cars is expected to grow significantly in the coming years as connectivity innovations transform the automotive industry. However, as with any other device that connects to the internet, cyber criminals pose a threat to automotive security. Personal data leaks, threats to a vehicle's essential security and safety mechanisms, and, in extreme cases, full remote control of the vehicle can all result from security breaches. And, as the industry moves toward more self-driving vehicles, these risks are only going to grow due to increased reliance on applications, connectivity, and more complex and integrated electronic components. Failure to address these risks could have disastrous consequences for consumer trust, privacy, and brand reputation. Worse, customer safety is jeopardized.

In this paper, the author discusses Layer-wise Security Challenges, Attack Vectors, and Architectural Flaws in the Physical layer by taking an example of a device connected to Connected cars and proposes a secure architectural solution for the Internet of Things (IoT) that assists in delivery teams in securely designing/architecting resource-intensive smart Internet of Things (IoT)/Narrowband (NIoT) use cases earlier in the Life cycle by employing the Secure Design Shift Left approach.

Keywords: internet of things (IoT), smart internet of things (SIoT); secure architecture design, secure design, secure engineering, unified secure architecture solution for IoT, connected cars.

I. Introduction

The Internet of Things (IoT) is a network of physical objects-"things"-embedded with sensors, software, and other technologies for connecting and exchanging data with other devices and systems via the internet.

These gadgets range from common household items to sophisticated industrial tools. Experts predict that the number of connected IoT devices will increase to 10 billion by 2020 and 22 billion by 2025, from more than 7 billion today. One of the classic examples of IoT is Connected Cars.

Figure 1: Internet of Things – Connected Car

Car owners can use IoT to remotely operate their vehicles, such as preheating the car before the driver gets in it or summoning a car via phone. Cars will be able to book their service appointments, and IoT can enable device-to-device communication. The connected car enables automakers or dealers to flip the car ownership model on its head. Previously, manufacturers maintained a distance from individual buyers. The manufacturer's relationship with the vehicle essentially ended when it was delivered to the dealer. Automobile manufacturers and dealers can maintain a continuous relationship with their customers by using connected cars. Instead of selling cars, they can charge drivers usage fees and provide "transportation-as-a-service" with self-driving cars. IoT enables car manufacturers to continuously upgrade their vehicles with new software, which is a significant departure from the traditional model of car ownership in which vehicles depreciate in performance and value.

The advantages to consumers are numerous: connectivity provides drivers with everything from high-definition streaming media to Wi-Fi access, improved

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entertainment systems, and the ability to remotely control aspects of the vehicle, such as the locking/ unlocking and ignition mechanisms, via mobile phone applications. IoT use cases include smart transportation, smart farming, smart grids, smart lighting, and connected vehicles.

In Smart/Connected farming, the use of technology to monitor, analyze, manage, control, and ultimately improve key agricultural processes at all stages of the farming cycle: pre-production, production, and post-production is referred to as connected farming.

Figure 2: Internet of Things – Connected Tractor for Farming needs

It entails the communication of various devices, starting with sensors in the field and progressing to smartphones in farmers' hands. To practice connected farming, a farmer should have IoT ecosystems in the field, agricultural equipment, the cloud, and the office, allowing for a 360-degree view of the entire farming cycle. As data is collected using sensor-equipped devices, this concept is closely related to IoT in agriculture. Devices can tell how moist the land is, allowing farmers to decide whether to irrigate or check nitrogen levels in the soil, allowing workers to decide whether to add more fertilizer. Crop drone imagery can also be used to determine whether pesticides should be applied.

However, because connected vehicles are so adaptable, they also present certain security risks.

When one device is physically connected to another, hackers can use a variety of methods to hack the system. Regardless of who owns the data, all stakeholders - the car fleet, Original Equipment Manufacturer (OEM), or a third-party Telematics Service Provider - are accountable for the telematics data's security.

While cyber-security has emerged as a key focus area for the automotive industry, OEMs are also investigating the topic because they must assess their products' cyber-security vulnerabilities. OEMs have significant IT and OT operations that are vulnerable to cyber threats, and they frequently lack the necessary internal resources to address the problem. Whether an in-house or third-party TSP, channel partners, and the OEM are all equally responsible for securing telematics data and gradually advancing the automotive industry to the next level of technological advancement.

In Section II of this paper, the author discusses various threats, attack vectors, and security challenges that hackers may use to hack IoT devices at the physical layer [1], and in Section III, the author discusses a Secure Architectural solution to mitigate these threats/ design challenges so that the underlying physical systems are safe and secure enough.

II. Layer-wise Security Challenges of Internet of Things (IOT) – Physical and Network Layers

To discuss the Security Challenges [1] or Threat Vectors [1] of IoT Connected Devices at the Physical Layer, we must first examine the underlying Architecture. We will be looking closely when we see a connected vehicle and evaluating a Connected Vehicle.

There were ECUs in all vehicles, whether they were cars, buses, tractors, or four-wheelers. ECUs, or Electronic Control Units, are critical components of a vehicle. In a car, multiple ECUs operate various features and control numerous parameters.

Vehicles with multiple electronic control units are divided in terms of what tasks they perform. Engine Control Modules, Brake Control Modules, Transmission Control Modules, Telematic Control Modules, Suspension Control Modules, and other ECUs are examples.

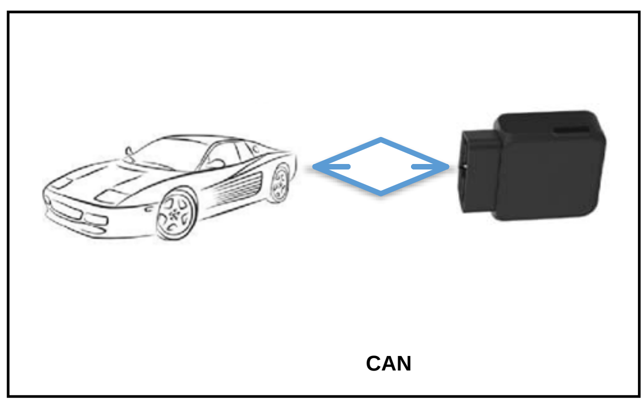

Figure 3: CAR ECU plugged with External Device via CAN

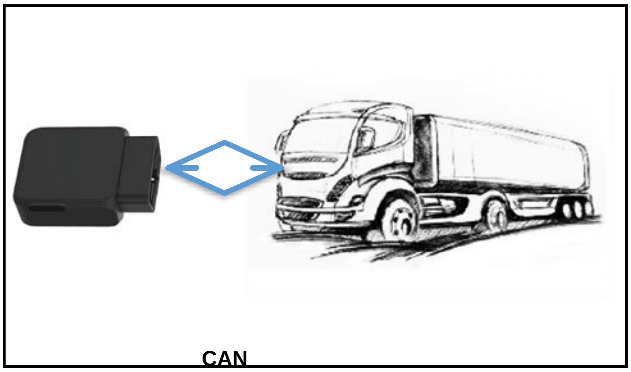

Figure 4: Heavy Vehicle ECU plugged with External Device via CAN

Simply put, an ECU is a device that controls all of the electronic features in a vehicle. This can include everything from fuel injection to maintaining a constant cabin temperature to controlling braking and suspension. Some vehicles have multiple ECUs that control different features, while others have a single ECU that controls everything.

Figure 5: ECU

Vehicles with multiple electronic control units are divided in terms of what tasks they perform. Engine Control Modules, Brake Control Modules, Transmission Control Modules, Telematic Control Modules, Suspension Control Modules, and other ECUs are examples.

An ECU is an electronic device with a memory filled with base numbers and parameters. With multiple IoT sensors around a vehicle feeding data to the ECU, it can efficiently manage and control the electronic systems by issuing orders to improve their output.

Consider how airbags [2] are deployed during an accident as an example of how an ECU controls something. The crash sensors are sensors located around the car that alert the ECU when a crash occurs. The ECU then measures the speed of the vehicle when it is involved in an accident and compares the data to determine whether or not the airbags should be deployed. If the data is sufficient, the ECU [3-4] will deploy the airbags. Take note that all of this happens in milliseconds.

The TCU collects telemetry data from the vehicle [5,6], such as position, speed, engine data, connectivity quality, and so on, by interfacing with various subsystems in the vehicle via data and control busses. It may also provide in-vehicle connectivity via Wifi and Bluetooth and, in certain markets, the eCall function. A TCU is made up of a satellite navigation (GNSS) unit that keeps track of the vehicle's latitude and longitude values; an external mobile communication interface (GSM, GPRS, Wi-Fi, WiMax, LTE, or 5G) that sends the tracked values to a centralized geographical information system (GIS) database server; an electronic processing unit; a microcontroller in some versions; a microprocessor or field programmable gate array (FPGA) that processes information and acts as an interface between the GPS; a mobile communication unit; and some memory for storing GPS values in mobile-free zones or intelligently storing information about the vehicle's sensor data.

TCU is linked to an external device for vehicle tracking. This device controls all of the vehicle's important features by reading and sending data. This external device reads data from the TCU's IOU (Input/output Unit) and correlates it using the SCU (Software/System Control Unit).

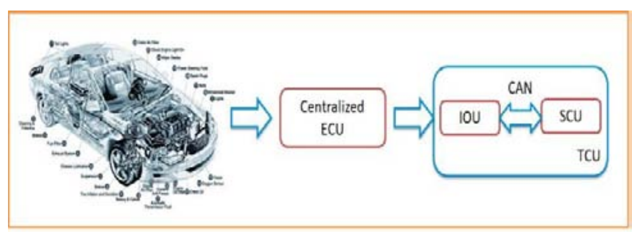

Figure 6: ECU'S Connectivity with TCU

The IOU receives all alerts/events from the ECU and correlates the data so that meaningful action can be taken. In the previous example, gathering all breakage-related information and correlating it to activate the airbags is the entire thing for which IOU will collect the dots. All of this data is sent to the SCU (Software Control Unit) via network connectivity.

Both IOU and SCU have traditionally been manufactured as separate components. Due to cybercrime, particularly via SCUs and IOU networks, all OEMs are producing SCUs and IOUs in a single unit known as TCU (Telemetry control unit), which is tightly coupled with both IOU and SCU.

Figure 7: SCU

Traditionally, OEMs connected the SCU unit to the IOU separately via CAN via Partners. As the threat vector grows, OEMs integrate this SCU unit inside the vehicle to prevent physical tampering. It is obvious that if the SCU is tampered with in any way, the entire vehicle can be controlled.

SCU is crucial, especially in connected vehicles. Having proper physical and information security controls that embed the SCU protects and secures the vehicle. The author discusses the various threat vectors that are possible for SCUs at the design level, which aids device hacking and thus controls the function of the entire connected vehicle in the following section.

III. Architectural Security Flaws, Threat Vectors in Respective Layers

In this section, the author discusses the potential threats for hacking the external device that is fitted/integrated with the OEM via CAN network to the ECU in light of the context discussed in the previous section.

a) Physical and Networking Layer – Security Challenges

Security Challenge/Threat Vector - 1: External Device Tampering

When it comes to SCU security, one of the threat vectors that comes to mind is device tampering. The hacker may tamper with the device and feed his/her special instructions to the device, causing the device to be controlled via his/her Command- and-Control. Device tampering is a very common security threat that the author must consider protecting a mechanism to safeguard architecturally/via Secure by Design.

2nd Security Challenge/Threat Vector: Replacing the Device/Stealing the Device

Replacing the SCU unit with a malicious SCU is another potential threat vector that could occur in real-world scenarios. A hacker may physically replace an algorithm-driven, C&C-controlled SCU with the device built into the vehicle and then take control of it. This is a serious security risk that can be mitigated by using secure design principles.

3rd Security Challenge/Threat Vector: Turning off the Device

In some cases, a hacker can disable the SCU device, preventing proper analytics from being fed to the server and, as a result, alarms from being triggered. This is most likely the threat that we see from traditional hackers. Switching off/unplugging the SCU may result in information not being shared with the IoT servers/ analytics platform, so we must consider this threat vector and find a meaningful solution to this challenge at the design level.

Resetting the Device is a security challenge/threat vector-4:

Resetting the device regularly after it has been hacked (or) sending malicious instructions to reset the device are common methods that the hacker can think of to escape the crime. OEMs and partners who build the SCU unit must consider how to solve this problem architecturally/at design levels.

5th Security Challenge/Threat Vector: Device Misconfiguration

There is a strong possibility that the device has been tampered with by maliciously configuring the device. Due to device misconfiguration, the OEM receives the incorrect feed being sent to the servers by overriding the actual instruction. One of the security threats that can be addressed architecturally is device misconfiguration.

Malicious command feeding to ECU is a security challenge/threat vector - 6.

Once the device has been tampered with by hackers, there is a strong possibility that the hacker will send malicious commands to the device to take control of the entire connected vehicle. Once this occurred, no one had control of the vehicle other than the hacker. Secure by Design must consider a kill chain to break this connection if the vehicle is already being controlled maliciously by the hacker.

Security Challenge/Threat Vector - 7: Response/ Communication Mechanism Tampering

When IOU receives a feed, IOU expects a response from the controlling IoT Server. There is an absolute risk that the connected car will be compromised if a man-in-the-middle who controls the SCU and IOU communication tampers with the packet response. Secure by design must address this challenge/threat vector on an architectural level.

Security Challenge/Threat Vector - 8: Network Choking

In some cases, hackers attempt to choke the network by sending unwanted requests/responses, resulting in the underlying network connection being choked, tainting the important information passing through the pipeline. The hacker gains control of the vehicle for a few minutes and causes damage to the vehicle's safety. One of the threats that Secure by Design must address is network choking.

Security Challenge/Threat Vector - 9: No Authentication/ Authorisation of the device in the Network

Authentication and authorization are critical in securing the physical device that is connected to the ECU. This is an important mechanism for identifying the original device to the vehicle OEM. The critical aspect to consider when designing devices architecturally is secure authentication and authorization.

Security Challenge/Threat Vector - 10: Loosely coupled protocols and tunneling of the device

While the SCU is connected to the IOU via the network, the underlying network and the protocol used for connectivity must be secure enough. When it comes to the protocol being used, strong algorithms for traffic encryption and secure tunneling are critical. Loosely coupled protocol exposes information to the man-in-the-middle and allows hackers to easily control the connected device. It must be very important when selecting the protocol to be used when connecting IOU to SCU. To mitigate protocol-related threats in the architecture, Secure by Design principles must be strong enough while suggest the underlying protocol.

IV. Unified Secure Architecture Solution Phsical & Network Layer Security Controls

In the preceding section, the author discussed the top ten security threats or challenges that are capable of jeopardizing the physical security of the device being integrated into the OEM. Though the author considered demonstrating the security threats by using Connected Vehicles as an example, imagine it in a way that if we plug a sensor device into any infrastructure, the challenges remain.

Having said that, the author discusses the Security Principles that can be used as a foundation for designing/architecting the Internet of Things (IoT) sensor via Secure by Design Architecturally in this section.

Architectural Solution: Physically Secure Sensor Devices by Design -

Consider the scenario with Connected Vehicle once more. The hacker may physically tamper with the SCU by removing the cover and attempting to change the chips (or) short-circuit (or) de-solder (or) additional solder of pins to change the behaviour pattern of the SCU motherboard.

The hacker must first open the container to remove the motherboard. So the challenge before us is to figure out how to keep the kill chain (or) a security control in place so that the OEM or user of the vehicle receives the alarm proactively.

The author proposes two techniques that can be used by OEMs or partners to mitigate this challenge.

Secure Architecture/Secure by Design – Physical tampering of chipboards/sensors

Let's take a closer look at the SCU device by opening it up. SCU is made up of a motherboard and a few integrated chips.

Figure 8: Tampered SCU

The author suggests two designs to prevent tampering.

1st Design:

Install magnetic sensors between the body and the motherboard. Magnetic sensors will continuously generate flux while keeping the circuit closed. When the motherboard is tampered with or removed from the cover, the flux circuit opens, and an inbuilt mechanism (message, continuous beep, or any mechanism that suits the OEM) activates the OEM to respond immediately.

Second Design:

Keep the motherboard inserted into the container and a Compression Spring pressed between the motherboard and the container. This pressure must be fed into the device for use as a reference. When someone tampers with/removes the motherboard, the pressure is released, which sends alerts to the OEM for immediate action.

One of the designs mentioned above can be used by vendors to reduce the risk of physical tampering with devices.

Secure Architecture/Secure by Design – Device Stealing

There must be a design mechanism in place to feed the sensor Longitudinal and Latitude data into the sensor to receive a notification if the device being integrated is tampered with or stolen. There must be a mechanism in place to notify the OEM if there is a change beyond 100 meters of the Long-Lat. In this way, we can reduce the likelihood of the device being stolen.

Secure Architecture/Secure by Design – Replacing the device

There must be a mechanism in place during OEM integration to allow the SCU and ECU to exchange trusted secrets, with the secret keys being asymmetric. Anyone attempting to tamper with the device with a different device will have these sensor-trusted secrets tampered with, and there will be an immediate mechanism to notify the OEM that the device is being replaced/tampered with.

Secure Architecture/Secure by Design – Switching off/resetting/coring the device

The hacker can reset, switch off, or coring the device through various means. There must be a secure-by-design approach where the hacker cannot turn off/ reset the device, including replacing the battery. OEMs must consider how best to remove the entire functionality of the device being reset/switched off within the quoted warranty period.

Secure Architecture/Secure by Design – Misconfiguration of the device

In most cases, when the hacker does not gain access to the device, he or she attempts to misconfigure it through various means. As part of the Secure by Design approach, OEMs must investigate the methods of a standard factory reset configuration, and any activities that touch the configuration must have the code built in such a way that it is intelligent enough to reset the entire configuration to its original form. This configuration must be encrypted and placed in the core, where only the system can command and reset.

Secure Architecture/Secure by Design – Man-in-the-Middle

There was a chance that the hacker could perform a man-in-the-middle attack while the IOU and SCU were communicating. A strong tunnelling mechanism must be established between IOU and SCU so that hackers cannot tamper with this connection. If this occurs, the system must be intelligent enough to reset the secure tunnel and establish it quickly. Strong encryption, whitelisted commands, whitelisted codes for both request and response, and pre-configured hashes known only to the whitelisted Requester and Responder will suffice for good security in secure tunnel communication. Strong Ciphers, hashes (independent packet (or) complete packet (with/without headers), Header hashes, and Body Hashes are a few types that OEMs can experiment with depending on their needs.

Secure Architecture/Secure by Design – Secure Communication

In general, all OEMs or Partners use the CAN protocol to communicate between the SCU and the IOU. The CAN [7, 8] bus's existing built-in security features are primarily intended to ensure reliable communication rather than cybersecurity; thus, they cannot protect the network from cyberattacks. As a result, cyberattacks on CAN [9,10] are expected to have far-reaching consequences. For example, an attack on an airbag [2] or ABS systems can jeopardize the driver's and passengers' safety.

It may eventually harm the reputation of the car manufacturer, with serious financial consequences such as recalls. Tampering with ECUs (for example, used-car odometers [5] is another example that could have serious consequences for consumers and manufacturers.

The lack of encryption in CAN is also concerning, as it has a significant impact on individual data privacy. CAN is a broadcast network by design, allowing nodes to capture messages as they travel through the network. An adversary can obtain the desired data because the broadcasted data is not encrypted. This may result in an invasion of privacy, especially since modern cars [10,11,12,13,14,15,16] are capable of acquiring personal information from the driver.

CAN attacks can be mitigated with network segmentation, encryption, authentication, and intrusion prevention systems. Several CAN vulnerabilities can be prevented by IPS with minimal overhead.

Hardware security modules (HSMs) integrate security functions directly into the main processors of ECUs. When used in conjunction with security software stacks, they prevent unauthorized access to in-vehicle communications and vehicle control. Security functions are encapsulated in hardware security modules, which are integrated chips designed specifically for security applications. Several of today's leading chip manufacturers, including Infineon, ST Microelectronics, Renesas, and NXP, are involved create HSMs suitable for use in vehicles These HSMs use their processor cores to provide all of the main IT security functions required for automotive use cases: a 128-bit AES hardware accelerator, a true random number generator (TRNG) to generate key material, hardware-protected storage of cryptographic keys, flash and debugging functions, and the HSM's processor cores.

Secure Architecture/Secure by Design – Tokenisation

Access Control Lists (ACLs) [18], Whitelisted Messages, and Tokenisation (Token life cycle - creation of tokens, expiry, safe shredding of tokens) are some methods for aiding in the analysis of communication between various actors. These are some of the security controls that must be implemented when designing secure physical devices.

V. Summary and Future Directions

As the geometric progression of IoT devices has increased, various threat vectors have emerged that allow hackers to gain an advantage over the system. Using Connected Vehicles as an example, the author discusses various threat vectors in the physical and network layers of IoT devices and has proposed the best ways to architect/design secure plug-and-play systems using the Secure by Design approach. Although a strong crypto protocol stack combined with Secure Tunnelling will solve the vast majority of transit traffic security challenges, there are some performance and narrowband resource concerns to be addressed. To assist IoT in building a strong tunnel, research must be conducted to address scanning delays and in-line scans, as well as to improve an efficient authentication and authorization process.

VI. Conclusions

In this paper, the author delves deeper into the IoT security flaws, threat vectors, actors, and various security challenges that affect the majority of IoT sensors (or) sensor-enabled devices physically; at the physical layer. The author used connected vehicles as an example to demonstrate the flaws and dug deep into them, discovering threats, threat vectors, and architecture design flaws, and determining the best way to design the system architecturally using Secure by Design. The discussion in Section II of this paper focused more on the Layer wise security challenges for IoT devices in the physical and network layers, using a Connected Vehicle as an example, and did a complete deep dive on understanding the flaws of connected vehicles and identifying the layer-wise security challenges. In Section III, the author identified architecture flaws and suggested the top ten flaws, and in Section IV, he provides a holistic approach to mitigating these security challenges/threats architecturally through the Secure by Design approach. Section V of this paper includes a summary and future directions for the next generation of researchers, as well as references and a summary.

VII. Declarations

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1. Substantial contributions to the conception and acquisition of data, analysis, and interpretation of findings.
2. Drafting the paper and revising it critically regarding important academic content.
3. Final approval of the version of the paper to be published.

Changes in Authorship

The corresponding author should mention the name and complete details of all co-authors during submission and in manuscript. We support addition, rearrangement, manipulation, and deletions in authors list till the early view publication of the journal. We expect that corresponding author will notify all co-authors of submission. We follow COPE guidelines for changes in authorship.

Copyright

During submission of the manuscript, the author is confirming an exclusive license agreement with Global Journals which gives Global Journals the authority to reproduce, reuse, and republish authors' research. We also believe in flexible copyright terms where copyright may remain with authors/employers/institutions as well. Contact your editor after acceptance to choose your copyright policy. You may follow this form for copyright transfers.

Appealing Decisions

Unless specified in the notification, the Editorial Board's decision on publication of the paper is final and cannot be appealed before making the major change in the manuscript.

Acknowledgments

Contributors to the research other than authors credited should be mentioned in Acknowledgments. The source of funding for the research can be included. Suppliers of resources may be mentioned along with their addresses.

Declaration of funding sources

Global Journals is in partnership with various universities, laboratories, and other institutions worldwide in the research domain. Authors are requested to disclose their source of funding during every stage of their research, such as making analysis, performing laboratory operations, computing data, and using institutional resources, from writing an article to its submission. This will also help authors to get reimbursements by requesting an open access publication letter from Global Journals and submitting to the respective funding source.

Preparing your Manuscript

Authors can submit papers and articles in an acceptable file format: MS Word (doc, docx), LaTeX (.tex, .zip or .rar including all of your files), Adobe PDF (.pdf), rich text format (.rtf), simple text document (.txt), Open Document Text (.odt), and Apple Pages (.pages). Our professional layout editors will format the entire paper according to our official guidelines. This is one of the highlights of publishing with Global Journals—authors should not be concerned about the formatting of their paper. Global Journals accepts articles and manuscripts in every major language, be it Spanish, Chinese, Japanese, Portuguese, Russian, French, German, Dutch, Italian, Greek, or any other national language, but the title, subtitle, and abstract should be in English. This will facilitate indexing and the pre-peer review process.

The following is the official style and template developed for publication of a research paper. Authors are not required to follow this style during the submission of the paper. It is just for reference purposes.

Manuscript Style Instruction (Optional)

- Microsoft Word Document Setting Instructions.
- Font type of all text should be Swis721 Lt BT.
- Page size: 8.27" x 11'", left margin: 0.65, right margin: 0.65, bottom margin: 0.75.
- Paper title should be in one column of font size 24.
- Author name in font size of 11 in one column.
- Abstract: font size 9 with the word "Abstract" in bold italics.
- Main text: font size 10 with two justified columns.
- Two columns with equal column width of 3.38 and spacing of 0.2.
- First character must be three lines drop-capped.
- The paragraph before spacing of 1 pt and after of 0 pt.
- Line spacing of 1 pt.
- Large images must be in one column.
- The names of first main headings (Heading 1) must be in Roman font, capital letters, and font size of 10.
- The names of second main headings (Heading 2) must not include numbers and must be in italics with a font size of 10.

Structure and Format of Manuscript

The recommended size of an original research paper is under 15,000 words and review papers under 7,000 words. Research articles should be less than 10,000 words. Research papers are usually longer than review papers. Review papers are reports of significant research (typically less than 7,000 words, including tables, figures, and references)

A research paper must include:

a) A title which should be relevant to the theme of the paper.
b) A summary, known as an abstract (less than 150 words), containing the major results and conclusions.
c) Up to 10 keywords that precisely identify the paper's subject, purpose, and focus.
d) An introduction, giving fundamental background objectives.
e) Resources and techniques with sufficient complete experimental details (wherever possible by reference) to permit repetition, sources of information must be given, and numerical methods must be specified by reference.
f) Results which should be presented concisely by well-designed tables and figures.
g) Suitable statistical data should also be given.
h) All data must have been gathered with attention to numerical detail in the planning stage.

Design has been recognized to be essential to experiments for a considerable time, and the editor has decided that any paper that appears not to have adequate numerical treatments of the data will be returned unrefereed.

i) Discussion should cover implications and consequences and not just recapitulate the results; conclusions should also be summarized.
j) There should be brief acknowledgments.
k) There ought to be references in the conventional format. Global Journals recommends APA format.

Authors should carefully consider the preparation of papers to ensure that they communicate effectively. Papers are much more likely to be accepted if they are carefully designed and laid out, contain few or no errors, are summarizing, and follow instructions. They will also be published with much fewer delays than those that require much technical and editorial correction.

The Editorial Board reserves the right to make literary corrections and suggestions to improve brevity.

Format Structure

It is necessary that authors take care in submitting a manuscript that is written in simple language and adheres to published guidelines.

All manuscripts submitted to Global Journals should include:

Title

The title page must carry an informative title that reflects the content, a running title (less than 45 characters together with spaces), names of the authors and co-authors, and the place(s) where the work was carried out.

Author details

The full postal address of any related author(s) must be specified.

Abstract

The abstract is the foundation of the research paper. It should be clear and concise and must contain the objective of the paper and inferences drawn. It is advised to not include big mathematical equations or complicated jargon.

Many researchers searching for information online will use search engines such as Google, Yahoo or others. By optimizing your paper for search engines, you will amplify the chance of someone finding it. In turn, this will make it more likely to be viewed and cited in further works. Global Journals has compiled these guidelines to facilitate you to maximize the web-friendliness of the most public part of your paper.

Keywords

A major lynchpin of research work for the writing of research papers is the keyword search, which one will employ to find both library and internet resources. Up to eleven keywords or very brief phrases have to be given to help data retrieval, mining, and indexing.

One must be persistent and creative in using keywords. An effective keyword search requires a strategy: planning of a list of possible keywords and phrases to try.

Choice of the main keywords is the first tool of writing a research paper. Research paper writing is an art. Keyword search should be as strategic as possible.

One should start brainstorming lists of potential keywords before even beginning searching. Think about the most important concepts related to research work. Ask, "What words would a source have to include to be truly valuable in a research paper?" Then consider synonyms for the important words.

It may take the discovery of only one important paper to steer in the right keyword direction because, in most databases, the keywords under which a research paper is abstracted are listed with the paper.

Numerical Methods

Numerical methods used should be transparent and, where appropriate, supported by references.

Abbreviations

Authors must list all the abbreviations used in the paper at the end of the paper or in a separate table before using them.

Formulas and equations

Authors are advised to submit any mathematical equation using either MathJax, KaTeX, or LaTeX, or in a very high-quality image.

Tables, Figures, and Figure Legends

Tables: Tables should be cautiously designed, uncrowned, and include only essential data. Each must have an Arabic number, e.g., Table 4, a self-explanatory caption, and be on a separate sheet. Authors must submit tables in an editable format and not as images. References to these tables (if any) must be mentioned accurately.

Figures

Figures are supposed to be submitted as separate files. Always include a citation in the text for each figure using Arabic numbers, e.g., Fig. 4. Artwork must be submitted online in vector electronic form or by emailing it.

Preparation of Eletronic Figures for Publication

Although low-quality images are sufficient for review purposes, print publication requires high-quality images to prevent the final product being blurred or fuzzy. Submit (possibly by e-mail) EPS (line art) or TIFF (halftone/ photographs) files only. MS PowerPoint and Word Graphics are unsuitable for printed pictures. Avoid using pixel-oriented software. Scans (TIFF only) should have a resolution of at least 350 dpi (halftone) or 700 to 1100 dpi (line drawings). Please give the data for figures in black and white or submit a Color Work Agreement form. EPS files must be saved with fonts embedded (and with a TIFF preview, if possible).

For scanned images, the scanning resolution at final image size ought to be as follows to ensure good reproduction: line art: >650 dpi; halftones (including gel photographs): >350 dpi; figures containing both halftone and line images: >650 dpi.

Color charges: Authors are advised to pay the full cost for the reproduction of their color artwork. Hence, please note that if there is color artwork in your manuscript when it is accepted for publication, we would require you to complete and return a Color Work Agreement form before your paper can be published. Also, you can email your editor to remove the color fee after acceptance of the paper.

Tips for Writing a Good Quality Engineering Research Paper

Techniques for writing a good quality engineering research paper:

1. Choosing the topic: In most cases, the topic is selected by the interests of the author, but it can also be suggested by the guides. You can have several topics, and then judge which you are most comfortable with. This may be done by asking several questions of yourself, like "Will I be able to carry out a search in this area? Will I find all necessary resources to accomplish the search? Will I be able to find all information in this field area?" If the answer to this type of question is "yes," then you ought to choose that topic. In most cases, you may have to conduct surveys and visit several places. Also, you might have to do a lot of work to find all the rises and falls of the various data on that subject. Sometimes, detailed information plays a vital role, instead of short information. Evaluators are human: The first thing to remember is that evaluators are also human beings. They are not only meant for rejecting a paper. They are here to evaluate your paper. So present your best aspect.

2. Think like evaluators: If you are in confusion or getting demotivated because your paper may not be accepted by the evaluators, then think, and try to evaluate your paper like an evaluator. Try to understand what an evaluator wants in your research paper, and you will automatically have your answer. Make blueprints of paper: The outline is the plan or framework that will help you to arrange your thoughts. It will make your paper logical. But remember that all points of your outline must be related to the topic you have chosen.

3. Ask your guides: If you are having any difficulty with your research, then do not hesitate to share your difficulty with your guide (if you have one). They will surely help you out and resolve your doubts. If you can't clarify what exactly you require for your work, then ask your supervisor to help you with an alternative. He or she might also provide you with a list of essential readings.

4. Use of computer is recommended: As you are doing research in the field of research engineering then this point is quite obvious. Use right software: Always use good quality software packages. If you are not capable of judging good software, then you can lose the quality of your paper unknowingly. There are various programs available to help you which you can get through the internet.

5. Use the internet for help: An excellent start for your paper is using Google. It is a wondrous search engine, where you can have your doubts resolved. You may also read some answers for the frequent question of how to write your research paper or find a model research paper. You can download books from the internet. If you have all the required books, place importance on reading, selecting, and analyzing the specified information. Then sketch out your research paper. Use big pictures: You may use encyclopedias like Wikipedia to get pictures with the best resolution. At Global Journals, you should strictly follow here.

6. Bookmarks are useful: When you read any book or magazine, you generally use bookmarks, right? It is a good habit which helps to not lose your continuity. You should always use bookmarks while searching on the internet also, which will make your search easier.

7. Revise what you wrote: When you write anything, always read it, summarize it, and then finalize it.

8. Make every effort: Make every effort to mention what you are going to write in your paper. That means always have a good start. Try to mention everything in the introduction—what is the need for a particular research paper. Polish your work with good writing skills and always give an evaluator what he wants. Make backups: When you are going to do any important thing like making a research paper, you should always have backup copies of it either on your computer or on paper. This protects you from losing any portion of your important data.

9. Produce good diagrams of your own: Always try to include good charts or diagrams in your paper to improve quality. Using several unnecessary diagrams will degrade the quality of your paper by creating a hodgepodge. So always try to include diagrams which were made by you to improve the readability of your paper. Use of direct quotes: When you do research relevant to literature, history, or current affairs, then use of quotes becomes essential, but if the study is relevant to science, use of quotes is not preferable.

10. Use proper verb tense: Use proper verb tenses in your paper. Use past tense to present those events that have happened. Use present tense to indicate events that are going on. Use future tense to indicate events that will happen in the future. Use of wrong tenses will confuse the evaluator. Avoid sentences that are incomplete.

11. Pick a good study spot: Always try to pick a spot for your research which is quiet. Not every spot is good for studying.

12. Know what you know: Always try to know what you know by making objectives, otherwise you will be confused and unable to achieve your target.

13. Use good grammar: Always use good grammar and words that will have a positive impact on the evaluator; use of good vocabulary does not mean using tough words which the evaluator has to find in a dictionary. Do not fragment sentences. Eliminate one-word sentences. Do not ever use a big word when a smaller one would suffice.

Verbs have to be in agreement with their subjects. In a research paper, do not start sentences with conjunctions or finish them with prepositions. When writing formally, it is advisable to never split an infinitive because someone will (wrongly) complain. Avoid clichés like a disease. Always shun irritating alliteration. Use language which is simple and straightforward. Put together a neat summary.

14. Arrangement of information: Each section of the main body should start with an opening sentence, and there should be a changeover at the end of the section. Give only valid and powerful arguments for your topic. You may also maintain your arguments with records.

15. Never start at the last minute: Always allow enough time for research work. Leaving everything to the last minute will degrade your paper and spoil your work.

16. Multitasking in research is not good: Doing several things at the same time is a bad habit in the case of research activity. Research is an area where everything has a particular time slot. Divide your research work into parts, and do a particular part in a particular time slot.

17. Never copy others' work: Never copy others' work and give it your name because if the evaluator has seen it anywhere, you will be in trouble. Take proper rest and food: No matter how many hours you spend on your research activity, if you are not taking care of your health, then all your efforts will have been in vain. For quality research, take proper rest and food.

18. Go to seminars: Attend seminars if the topic is relevant to your research area. Utilize all your resources.

19. Refresh your mind after intervals: Try to give your mind a rest by listening to soft music or sleeping in intervals. This will also improve your memory. Acquire colleagues: Always try to acquire colleagues. No matter how sharp you are, if you acquire colleagues, they can give you ideas which will be helpful to your research.

20. Think technically: Always think technically. If anything happens, search for its reasons, benefits, and demerits. Think and then print: When you go to print your paper, check that tables are not split, headings are not detached from their descriptions, and page sequence is maintained.

21. Adding unnecessary information: Do not add unnecessary information like "I have used MS Excel to draw graphs." Irrelevant and inappropriate material is superfluous. Foreign terminology and phrases are not apropos. One should never take a broad view. Analogy is like feathers on a snake. Use words properly, regardless of how others use them. Remove quotations. Puns are for kids, not grunt readers. Never oversimplify: When adding material to your research paper, never go for oversimplification; this will definitely irritate the evaluator. Be specific. Never use rhythmic redundancies. Contractions shouldn't be used in a research paper. Comparisons are as terrible as clichés. Give up ampersands, abbreviations, and so on. Remove commas that are not necessary. Parenthetical words should be between brackets or commas. Understatement is always the best way to put forward earth-shaking thoughts. Give a detailed literary review.
22. Report concluded results: Use concluded results. From raw data, filter the results, and then conclude your studies based on measurements and observations taken. An appropriate number of decimal places should be used. Parenthetical remarks are prohibited here. Proofread carefully at the final stage. At the end, give an outline to your arguments. Spot perspectives of further study of the subject. Justify your conclusion at the bottom sufficiently, which will probably include examples.
23. Upon conclusion: Once you have concluded your research, the next most important step is to present your findings. Presentation is extremely important as it is the definite medium though which your research is going to be in print for the rest of the crowd. Care should be taken to categorize your thoughts well and present them in a logical and neat manner. A good quality research paper format is essential because it serves to highlight your research paper and bring to light all necessary aspects of your research.

Informal Guidelines of Research Paper Writing

Key points to remember:

- Submit all work in its final form.
- Write your paper in the form which is presented in the guidelines using the template.
- Please note the criteria peer reviewers will use for grading the final paper.

Final points:

One purpose of organizing a research paper is to let people interpret your efforts selectively. The journal requires the following sections, submitted in the order listed, with each section starting on a new page:

The introduction: This will be compiled from reference matter and reflect the design processes or outline of basis that directed you to make a study. As you carry out the process of study, the method and process section will be constructed like that. The results segment will show related statistics in nearly sequential order and direct reviewers to similar intellectual paths throughout the data that you gathered to carry out your study.

The discussion section:

This will provide understanding of the data and projections as to the implications of the results. The use of good quality references throughout the paper will give the effort trustworthiness by representing an alertness to prior workings.

Writing a research paper is not an easy job, no matter how trouble-free the actual research or concept. Practice, excellent preparation, and controlled record-keeping are the only means to make straightforward progression.

General style:

Specific editorial column necessities for compliance of a manuscript will always take over from directions in these general guidelines.

To make a paper clear: Adhere to recommended page limits.

Mistakes to avoid:

- Insertion of a title at the foot of a page with subsequent text on the next page.
- Separating a table, chart, or figure—confine each to a single page.
- Submitting a manuscript with pages out of sequence.
- In every section of your document, use standard writing style, including articles ("a" and "the").
- Keep paying attention to the topic of the paper.

- Use paragraphs to split each significant point (excluding the abstract).
- Align the primary line of each section.
- Present your points in sound order.
- Use present tense to report well-accepted matters.
- Use past tense to describe specific results.
- Do not use familiar wording; don't address the reviewer directly. Don't use slang or superlatives.
- Avoid use of extra pictures—include only those figures essential to presenting results.

Title page:

Choose a revealing title. It should be short and include the name(s) and address(es) of all authors. It should not have acronyms or abbreviations or exceed two printed lines.

Abstract: This summary should be two hundred words or less. It should clearly and briefly explain the key findings reported in the manuscript and must have precise statistics. It should not have acronyms or abbreviations. It should be logical in itself. Do not cite references at this point.

An abstract is a brief, distinct paragraph summary of finished work or work in development. In a minute or less, a reviewer can be taught the foundation behind the study, common approaches to the problem, relevant results, and significant conclusions or new questions.

Write your summary when your paper is completed because how can you write the summary of anything which is not yet written? Wealth of terminology is very essential in abstract. Use comprehensive sentences, and do not sacrifice readability for brevity; you can maintain it succinctly by phrasing sentences so that they provide more than a lone rationale. The author can at this moment go straight to shortening the outcome. Sum up the study with the subsequent elements in any summary. Try to limit the initial two items to no more than one line each.

Reason for writing the article—theory, overall issue, purpose.

- Fundamental goal.
- To-the-point depiction of the research.
- Consequences, including definite statistics—if the consequences are quantitative in nature, account for this; results of any numerical analysis should be reported. Significant conclusions or questions that emerge from the research.

Approach:

- o Single section and succinct.
- o An outline of the job done is always written in past tense.
- o Concentrate on shortening results—limit background information to a verdict or two.
- o Exact spelling, clarity of sentences and phrases, and appropriate reporting of quantities (proper units, important statistics) are just as significant in an abstract as they are anywhere else.

Introduction:

The introduction should "introduce" the manuscript. The reviewer should be presented with sufficient background information to be capable of comprehending and calculating the purpose of your study without having to refer to other works. The basis for the study should be offered. Give the most important references, but avoid making a comprehensive appraisal of the topic. Describe the problem visibly. If the problem is not acknowledged in a logical, reasonable way, the reviewer will give no attention to your results. Speak in common terms about techniques used to explain the problem, if needed, but do not present any particulars about the protocols here.

The following approach can create a valuable beginning:

- o Explain the value (significance) of the study.
- o Defend the model—why did you employ this particular system or method? What is its compensation? Remark upon its appropriateness from an abstract point of view as well as pointing out sensible reasons for using it.
- o Present a justification. State your particular theory(-ies) or aim(s), and describe the logic that led you to choose them.
- o Briefly explain the study's tentative purpose and how it meets the declared objectives.

Approach:

Use past tense except for when referring to recognized facts. After all, the manuscript will be submitted after the entire job is done. Sort out your thoughts; manufacture one key point for every section. If you make the four points listed above, you will need at least four paragraphs. Present surrounding information only when it is necessary to support a situation. The reviewer does not desire to read everything you know about a topic. Shape the theory specifically—do not take a broad view.

As always, give awareness to spelling, simplicity, and correctness of sentences and phrases.

Procedures (methods and materials):

This part is supposed to be the easiest to carve if you have good skills. A soundly written procedures segment allows a capable scientist to replicate your results. Present precise information about your supplies. The suppliers and clarity of reagents can be helpful bits of information. Present methods in sequential order, but linked methodologies can be grouped as a segment. Be concise when relating the protocols. Attempt to give the least amount of information that would permit another capable scientist to replicate your outcome, but be cautious that vital information is integrated. The use of subheadings is suggested and ought to be synchronized with the results section.

When a technique is used that has been well-described in another section, mention the specific item describing the way, but draw the basic principle while stating the situation. The purpose is to show all particular resources and broad procedures so that another person may use some or all of the methods in one more study or referee the scientific value of your work. It is not to be a step-by-step report of the whole thing you did, nor is a methods section a set of orders.

Materials:

Materials may be reported in part of a section or else they may be recognized along with your measures.

Methods:

- Report the method and not the particulars of each process that engaged the same methodology.
- Describe the method entirely.
- To be succinct, present methods under headings dedicated to specific dealings or groups of measures.
- Simplify—detail how procedures were completed, not how they were performed on a particular day.
- If well-known procedures were used, account for the procedure by name, possibly with a reference, and that's all.

Approach:

It is embarrassing to use vigorous voice when documenting methods without using first person, which would focus the reviewer's interest on the researcher rather than the job. As a result, when writing up the methods, most authors use third person passive voice.

Use standard style in this and every other part of the paper—avoid familiar lists, and use full sentences.

What to keep away from:

- Resources and methods are not a set of information.
- Skip all descriptive information and surroundings—save it for the argument.
- Leave out information that is immaterial to a third party.

Results:

The principle of a results segment is to present and demonstrate your conclusion. Create this part as entirely objective details of the outcome, and save all understanding for the discussion.

The page length of this segment is set by the sum and types of data to be reported. Use statistics and tables, if suitable, to present consequences most efficiently.

You must clearly differentiate material which would usually be incorporated in a study editorial from any unprocessed data or additional appendix matter that would not be available. In fact, such matters should not be submitted at all except if requested by the instructor.

Content:

- Sum up your conclusions in text and demonstrate them, if suitable, with figures and tables.
- In the manuscript, explain each of your consequences, and point the reader to remarks that are most appropriate.
- Present a background, such as by describing the question that was addressed by creation of an exacting study.
- Explain results of control experiments and give remarks that are not accessible in a prescribed figure or table, if appropriate.
- Examine your data, then prepare the analyzed (transformed) data in the form of a figure (graph), table, or manuscript.

What to stay away from:

- Do not discuss or infer your outcome, report surrounding information, or try to explain anything.
- Do not include raw data or intermediate calculations in a research manuscript.
- Do not present similar data more than once.
- A manuscript should complement any figures or tables, not duplicate information.
- Never confuse figures with tables—there is a difference.

Approach:

As always, use past tense when you submit your results, and put the whole thing in a reasonable order.

Put figures and tables, appropriately numbered, in order at the end of the report.

If you desire, you may place your figures and tables properly within the text of your results section.

Figures and tables:

If you put figures and tables at the end of some details, make certain that they are visibly distinguished from any attached appendix materials, such as raw facts. Whatever the position, each table must be titled, numbered one after the other, and include a heading. All figures and tables must be divided from the text.

Discussion:

The discussion is expected to be the trickiest segment to write. A lot of papers submitted to the journal are discarded based on problems with the discussion. There is no rule for how long an argument should be.

Position your understanding of the outcome visibly to lead the reviewer through your conclusions, and then finish the paper with a summing up of the implications of the study. The purpose here is to offer an understanding of your results and support all of your conclusions, using facts from your research and generally accepted information, if suitable. The implication of results should be fully described.

Infer your data in the conversation in suitable depth. This means that when you clarify an observable fact, you must explain mechanisms that may account for the observation. If your results vary from your prospect, make clear why that may have happened. If your results agree, then explain the theory that the proof supported. It is never suitable to just state that the data approved the prospect, and let it drop at that. Make a decision as to whether each premise is supported or discarded or if you cannot make a conclusion with assurance. Do not just dismiss a study or part of a study as "uncertain."

Research papers are not acknowledged if the work is imperfect. Draw what conclusions you can based upon the results that you have, and take care of the study as a finished work.

- You may propose future guidelines, such as how an experiment might be personalized to accomplish a new idea.
- Give details of all of your remarks as much as possible, focusing on mechanisms.
- Make a decision as to whether the tentative design sufficiently addressed the theory and whether or not it was correctly restricted. Try to present substitute explanations if they are sensible alternatives.
- One piece of research will not counter an overall question, so maintain the large picture in mind. Where do you go next? The best studies unlock new avenues of study. What questions remain?
- Recommendations for detailed papers will offer supplementary suggestions.

Approach:

When you refer to information, differentiate data generated by your own studies from other available information. Present work done by specific persons (including you) in past tense.

Describe generally acknowledged facts and main beliefs in present tense.

The Administration Rules

Administration Rules to Be Strictly Followed before Submitting Your Research Paper to Global Journals Inc.

Please read the following rules and regulations carefully before submitting your research paper to Global Journals Inc. to avoid rejection.

Segment draft and final research paper: You have to strictly follow the template of a research paper, failing which your paper may get rejected. You are expected to write each part of the paper wholly on your own. The peer reviewers need to identify your own perspective of the concepts in your own terms. Please do not extract straight from any other source, and do not rephrase someone else's analysis. Do not allow anyone else to proofread your manuscript.

Written material: You may discuss this with your guides and key sources. Do not copy anyone else's paper, even if this is only imitation, otherwise it will be rejected on the grounds of plagiarism, which is illegal. Various methods to avoid plagiarism are strictly applied by us to every paper, and, if found guilty, you may be blacklisted, which could affect your career adversely. To guard yourself and others from possible illegal use, please do not permit anyone to use or even read your paper and file.

Criterion for Grading a Research Paper (Compilation) by Global Journals

Please note that following table is only a Grading of "Paper Compilation" and not on "Performed/Stated Research" whose grading solely depends on Individual Assigned Peer Reviewer and Editorial Board Member. These can be available only on request and after decision of Paper. This report will be the property of Global Journals.

Topics	Grades		
	A-B	**C-D**	**E-F**
Abstract	Clear and concise with appropriate content, Correct format. 200 words or below	Unclear summary and no specific data, Incorrect form Above 200 words	No specific data with ambiguous information Above 250 words
Introduction	Containing all background details with clear goal and appropriate details, flow specification, no grammar and spelling mistake, well organized sentence and paragraph, reference cited	Unclear and confusing data, appropriate format, grammar and spelling errors with unorganized matter	Out of place depth and content, hazy format
Methods and Procedures	Clear and to the point with well arranged paragraph, precision and accuracy of facts and figures, well organized subheads	Difficult to comprehend with embarrassed text, too much explanation but completed	Incorrect and unorganized structure with hazy meaning
Result	Well organized, Clear and specific, Correct units with precision, correct data, well structuring of paragraph, no grammar and spelling mistake	Complete and embarrassed text, difficult to comprehend	Irregular format with wrong facts and figures
Discussion	Well organized, meaningful specification, sound conclusion, logical and concise explanation, highly structured paragraph reference cited	Wordy, unclear conclusion, spurious	Conclusion is not cited, unorganized, difficult to comprehend
References	Complete and correct format, well organized	Beside the point, Incomplete	Wrong format and structuring

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