1. DETAILED DESCRIPTION

The Essence of the Solution: a Framework for new Levels of Precision and Certainty

The proposed solution is not a process for capturing ICP measurements. Instead, it consists of two software methods to compare any variety of contributing factors and to evaluate their respective effects. This includes the benefits and disadvantages of imaging and other measuring technologies.

By providing ‘meta technology views’ of ICP measurements, it is hoped that the complexity surrounding absolute measurements in varying space environments will be better understood, as far as the relevance of contributing factors is concerned, so that informed choices will pick the right technologies.
The methods add visual depth, newly discernible details and numerical accuracy to measurement series produced by existing technologies. They are the core of ‘smart knowledge systems’ to combine the best of human expertise: visual interpretation, with the best of computer processing: numerical analysis.

**Two Software Methods: Tools for Investigation and Evaluation**

‘Image metrics’ is the basis for quantifying on-screen what happens in brains and their environments. As a purely numerical method, it offers new levels of comparison and degrees of accuracy. Whilst theoretical claims are proven by prototype software, further software development is required for eventually choosing the optimal imaging technology as well as image conditions for references. Software development includes experts in brain images as well as the chosen technologies. Their expertise is ‘embedded’ to combine computer analysis with human interpretation.

As a second software method, ‘vertical data layering’ is proposed to analyse factors that contribute to intracranial pressure measurements on the ground and in flight.

The re-visualization of an fMRI image shows more depth and detail for the expert user to see.

In addition, the software derives metrics for the expert to interpret – as ‘attributes’ of intracranial pressure or other contributing factors.

As a second software method, ‘vertical data layering’ is proposed to analyse factors that contribute to intracranial pressure measurements on the ground and in flight.

The ‘layering’ of multi-dimensional data allows for instant visual comparisons to spot extremes, differences and correlations. User interfaces will allow for critical evaluation.

The Solver is confident about being able to deliver the solution as a web portal of analysis on the ground. However, in-flight monitoring requires suitable equipment to generate data and images.

**Image Metrics: the Answer to Einstein’s Critique of Mathematics & Uncertainty**

"As far as the laws of mathematics refer to reality, they are not certain; as far as they are certain, they do not refer to reality." In private and independent research, the Solver has found that his innovative image metrics refers to reality not only with certainty, but also consistently, at any scale, across any imaging technology.

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Image metrics are used for:

- analysing imaging technologies, representing reality at telescopic or microscopic scale
  - e.g. MRI, OCT and ultrasound can be compared in their respective advantages of measuring intracranial pressure
  - the choice of technology depends on the highest degree of ‘pixel accuracy’ obtainable
- ‘smart knowledge portals’, as measuring instruments for on-screen evaluation, combine human expertise of interpretation with the power of computing for analysis, especially large quantities
  - expert users ‘embed’ what they see as ‘quantitative characteristics’
  - to define selection criteria
  - less skilled users can then operate automated systems
  - to select particularly interesting ones as well as the odd ones out
- ‘software lenses’, as instruments of investigation, are not varied mechanically to change views and perspectives, but by software parameters for different levels of users and purposes of examination
  - Quantitative characteristics and pixel accuracy resolve uncertainties and probabilities inherent in physical measurements.

Measuring On-Screen: a Novel Non-Destructive Testing Method

In particular, image metrics are used to determine

- an imaging technology for reference purposes
  - to represent ICP with the best possible images and their optimal re-visualizations
- parameters and conditions for reference images
  - to establish values of significance for key regions of major interest
- attributes and specifications for reference values
  - personal reference values for ICP on the ground
  - lower and upper limits for criteria such that images can be selected from series
    - according to particular regions of interest
    - over chosen time periods
    - on the ground or in flight.

By operating automated systems over hundreds and thousands of images over time, averages can be established that, eventually, will lead to medical standards of conditions of illness and health—both on the ground and in-flight—for every particular astronaut as well as the general public.

In summary:

- re-visualizations of digital images allow for analysing visually
  - any imaging technology at any scale
  - differences between ICP measurements in different conditions
- comparative evaluation of image technologies is provided by
  - image metrics and quantitative characteristics
- comparative evaluation of measuring technologies is facilitated by
  - parallel layering of measurement series.
'Quantitative Characteristics': a Result of the ‘Physics of Information’ and the 'Metrics of Images'

Metrology is based on the physics of electricity and magnetism, gravity and the speed of light. This is also the foundation for measuring intracranial pressure (ICP) in mm of mercury (mmHg).²

Image metrics, however, is based on the physics of information and the digits that make up images. This information includes the translation of light and colour into numerical values. Different imaging technologies create different values and the same technology creates different values over time, if physical or medical conditions change.

Visual and numerical comparisons are the key characteristics of image metrics for measuring on-screen by re-visualizing images with more depth, detail and accuracy and analysing them numerically.

As users, image experts interpret what re-visualizations tell them and attribute the values that the software offers to quantitative characteristics. These may describe new aspects, qualities or conditions that contribute to ICP as the physical phenomenon to be monitored.

Making use of image metrics for this solution thus begins with recognizing how intracranial pressure shows up with different imaging technologies – both for the trained eye and the numerical mind:

- What does the re-visualization of an image reveal thanks to new depth and detail?
- What do the metrics quantify in addition to intracranial pressure values?

The more images are re-visualized and analysed, the better lower and upper limits are established for physical, chemical and biological qualities as metric characteristics, that contribute to brain processes in general and intracranial pressure in particular, over short, medium and long time periods.

When deciding which technology should be developed for space flights, mass, volume and power needs are clearly paramount. When deciding how to combine real time monitoring with pre- and post-flight processing and comparisons, software and hardware requirements need to be considered.

Contributors to ICP Measurements: Internal and External Factors

Internal contributors to ICP measurements are brain tissue, blood and cerebrospinal fluid (CSF). Furthermore, the body automatically balances its intracranial pressure and adapts to its environment. The result is a single value that represents an ICP measurement in mmHg.

MmHg (millimeter of mercury) is defined by

- the pressure exerted at the base of a column of fluid exactly 1 mm high
- when the density of fluid is exactly 13.5951 g/cm³
  - which assumes a temperature of 0°C
  - and atmospheric pressure equivalent to 760 mmHg
  - where atmospheric pressure depends on temperature, air density, altitude and humidity
- at a place where the acceleration of gravity is exactly 9.80665 m/s².

² [http://en.wikipedia.org/wiki/MmHg#mmHg](http://en.wikipedia.org/wiki/MmHg#mmHg)
ICP measurements in mmHg are thus the result of many factors contributing to a complex phenomenon that is critical to human health on ground and in space.

**Monitoring Intracranial Pressure Measurements**

Re-visualizations of images are a particular ‘use case’ of proprietary data transformations that can be applied to multi-dimensional data or time series such as ICP measurements.

Time series of ICP measurements produced by other technologies can thus also be visually compared and studied – via a browser – as Software As A Service.

In the framework of ‘the physics of information’, the comparative study of ICP measurements taken by different technologies over time will contribute to the interpretation of image metrics offered on the ground. Whether this functionality is desirable in flight remains to be considered.

In any case, the proposed solution could lead to far reaching research resulting in many new insights that may also lead to innovating metric devices.

Monitoring ICP measurements with any of the non-imaging technologies in addition to using image metrics would serve to understand the complexity of the interchange between physical, chemical and biological processes in flight and on the ground, while measurements could be compared over time. This functionality could also be considered as an ‘add-on’ to other solutions proposed.

### 2. RATIONALE for ACCURATE MEASUREMENTS of ABSOLUTE ICP

**The Absoluteness of ICP Measurements as a Physical and Metrological Challenge**

*Pixel accuracy* guarantees a new level of precision on-screen. The *absoluteness* of measuring deserves further consideration, however.

Due to the definition of *mmHg* as measuring unit for ICP, any measurement is relative to the atmospheric pressure present on the ground or the height of the flight as the primary factor of influence. For *mmHg* includes atmospheric pressure and the acceleration of gravity. To examine all factors of influence, the two software methods proposed can be used to examine

- the accuracy provided by differing technologies
- the primary importance and relevance of contributing factors and their variations
- with a view to determining benchmarks of absoluteness.

By investigating the influence and significance of other contributing factors as metric characteristics, it will become possible to establish measurements with ‘absolute relativity’. For ‘references of relativity’ can be established with atmospheric pressure on top of the list.
The importance of **non-invasive ICP measurement methods** has also been formulated in Wikipedia. Comparable to blood pressure, the variation of ICP depends on a number of bodily functions that adapt to ground and flight environments:

- the principal intracranial contributors are brain, blood and CSF
- external contributors depend on other bodily functions and conditions
- the physical environment on ground and in space contribute with atmospheric pressure and the acceleration of gravity.

When using *mmHg measurements* by one or more technologies as *benchmark*, the Solver offers two approaches towards ascertaining the significance of all possible contributing factors and thus the ‘absoluteness’ of potential benchmarks:

- **metrics of images** serves to quantify
  - contributing factors such as oxygen levels and blood pressure, are formulated by expert users who examine their *relevance*, if possible, with both approaches on offer
  - ground conditions are expressed in terms of atmospheric pressure as ‘zero references’
  - flight conditions are expressed in terms of atmospheric pressure as ‘gauge pressures’

- **vertical layering of ICP measurement series** serves to compare, contrast and detect
  - the *significance of differences* between various technologies
  - an *appreciation* of their respective unique characteristics
  - and the necessary *prioritisation* of their respective contributions to fully understand all processes involved over short, medium and long time periods.

**References on the Ground**

Image metrics and vertical layering of ICP measurement series offer a new scope for research, by investigating both images and ICP measurement series. Ground conditions will always provide references to compare with the effects of flight conditions.

**References in Flight**

However, the absoluteness of any quantification of any measuring unit depends on

- zero-references
- gauge conditions
- and metric benchmarks.

The challenge of the absoluteness of measurements in mmHg can conceivably be reduced to comparing results on the ground with results at different heights in flight.

But the real question is whether ICP is the top indicator of human adaption to space conditions.

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3. ESTIMATION of TECHNOLOGY READINESS LEVELS

TRL 1: Basic principles have been observed and reported
Yes.

TRL 2: Technology concept and/or application has been formulated
On ground: yes; in flight: no.

TRL 3: Analytical and experimental evidence has been obtained for the critical function, and or characteristic proof-of-concept evidence has been documented
Yes with prototype software.

TRL 4: The key component or “breadboard” has been validated in a laboratory environment
A ‘smart knowledge portal’ is not operational yet.

TRL 5: The key component or “breadboard” has been validated in the relevant test environment
No; but the software specifications have been formulated.

TRL 6: A complete system or subsystem model or prototype has been completed in a relevant test environment (ground- or space-based)
No. The technology translation from ground to space requires work.

4. SUPPORTING INFORMATION

The known technologies listed in the Challenge comprise:

Imaging Technologies – which can be compared numerically and visually with ‘image metrics’:
• Magnetic resonance imaging (MRI)
• Ultrasound
• Optical Coherence Tomography (OCT)

Other Technologies contributing Time Series – which can be compared visually and numerically with ‘layering’:
• Cerebral and Cochlear Fluid Pressure (CCFP)
• Ophthalmodynamometry
• Distortion Product Otoacoustic Emissions (DPOAE)
• Pulse Phase Lock Loop (PPLL)
• Dual-depth ultrasound (Vittamed)

TECHNICAL REQUIREMENTS

1. Consistently accurate results
   a. No problem
2. Completely non-invasive
   a. Ensured
3. Monitoring over time
   a. Main strength
4. On the ground and in space
   a. Perfect on the ground but requires development for space
5. Radiation exposure
   a. No problem regarding software methods provided as a service.