# Space Ordinals

**Intuitive, Unambiguous, and Universal Numerals for the Space Age**

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## Executive Summary

As humanity expands its presence in space and explores virtual environments, traditional numbering systems face limitations due to their inherent orientation dependence. The lack of a fixed "up" or "down" in zero-gravity or virtual spaces leads to potential misinterpretations and costly errors in labeling and communication. Space Ordinals address this issue—a non-ambiguous numbering system designed for universal communication in challenging environments. Space Ordinals utilize a circular pendant style with unique geometric patterns, ensuring readability regardless of orientation. These symbols are intuitive, robust against defacement, and suitable for international and intergalactic collaboration. Imagine a future where engineers from different countries(or planets) can collaborate on a space mission using a common, orientation-independent numbering system. This white paper details the problem of numerical ambiguity, presents Space Ordinals as the solution, and provides evidence for their effectiveness and potential implementation across various applications, including space operations and board games.

## Introduction

In an increasingly interconnected world, where human endeavors extend beyond terrestrial boundaries into the vast expanse of space and the intricate landscapes of virtual environments, the clarity and precision of communication become paramount. Among the fundamental communication tools, numbering systems are critical in organizing, identifying, and managing information. However, traditional numbering systems, rooted in our Earthly experience, are inherently tied to orientation. These systems assume a definitive "up" and "down," a left-to-right reading order, and are often visually dependent on the clarity of symbols. This orientation dependence, which works seamlessly in our daily lives, presents significant challenges in environments lacking a fixed orientation, such as zero-gravity conditions in space or within immersive virtual realities.

The potential for costly errors in traditional numbering systems is a pressing concern. The ambiguity arising from these orientation-dependent notations can lead to misinterpretations and potential accidents, especially in high-stakes environments like space operations or complex industrial settings. What appears as "989" in one orientation

can easily be misread as "686" when rotated, illustrating the fragility of conventional numerical representation under non-standard conditions.

To address this pressing issue, this white paper introduces Space Ordinals, a novel Multi Orientation Non-Ambiguous Notation (MONAN) designed to transcend these limitations. Space Ordinals provide a set of intuitive, robust, and universally readable symbols, ensuring clarity and precision irrespective of their orientation. These symbols are designed to be read from any direction, eliminating the need for a fixed orientation. For example, a Space Ordinal that looks like a circle with a line through it can be read as '1' from any direction. This paper will explore the challenges posed by traditional numbering systems in specialized environments, detail the principles and design of Space Ordinals, and demonstrate their potential applications and benefits across various fields, from space exploration to interactive board games.

## Problem Statement

As humanity ventures further into space and delves deeper into immersive virtual environments, we encounter a fundamental limitation with our current methods of representing and interpreting numerical information. Traditional numbering systems, deeply ingrained in our terrestrial experience, are designed with the assumption of a fixed orientation. They rely on a consistent "up" and "down," a left-to-right reading order, and the clear, unobstructed visibility of specific symbols. This inherent orientation dependence poses significant challenges in environments where these assumptions do not hold.

In zero-gravity conditions, such as those experienced in space travel or orbiting stations, "up" and "down" become arbitrary. A number that appears as "989" in one orientation can be easily misread as "686" when rotated. This ambiguity is not merely a theoretical concern. Such misinterpretations can lead to costly logistical mistakes, system malfunctions, and potentially dangerous accidents in operational contexts. For instance, mislabeling cargo, equipment, or navigation coordinates can result in significant delays, resource waste, or critical errors in mission planning and execution.

The problem extends beyond the challenges of zero-gravity environments. In dense industrial plants, intricate engineering simulations, or when viewing information through reflections or transparent media, the lack of a clear orientation can similarly lead to confusion and errors. In these situations, ambiguity can result in misidentified conduits or cables, incorrect assembly procedures, and compromised safety.

Furthermore, a second significant challenge arises from occlusions, defacements, and lighting effects. Traditional numerical symbols can be rendered illegible or misinterpreted

due to partial obstruction, damage, or poor lighting conditions. What might appear as an "8" with a smudge might be a "0," compounding the issue of orientation dependence.

Consider the following illustrative scenarios:

- **Scenario 1:** In a space station, an astronaut needs to locate a specific component labeled "090." However, due to the lack of a fixed orientation, they might inadvertently search for "060," causing a delay in critical repairs.
- **Scenario 2:** In a virtual engineering simulation, an engineer tries to identify specific data points represented by numerical values. Due to the simulation's multi-perspective nature, the displayed numbers are difficult to read and interpret consistently, leading to analysis errors.
- **Scenario 3:** A storage container labeled with a number is partially defaced during transit. The ambiguity resulting from the damaged symbol leads to the wrong inventory being dispatched, disrupting supply chain logistics.

These examples underscore the critical need for a robust, unambiguous, and orientation-independent numbering system. The limitations of traditional notations are clear, and a solution that transcends these limitations is essential for clear and reliable communication in all environments.

In addition to the challenges posed by orientation dependence in zero-gravity and virtual environments, traditional numbering systems are vulnerable to deliberate falsification and accidental alteration. These systems rely on easily modifiable symbols, which can be readily changed to represent different values. This vulnerability introduces a critical security and accuracy issue in environments where precise identification is essential.

Consider the following vulnerabilities:

- **Symbol Transformation:** Traditional numerical symbols can be easily altered. A "3" can be changed into an "8" with minimal effort, introducing errors that are difficult to detect visually. This issue is further compounded by handwritten or hastily applied numbers.
- **Digit Manipulation:** Digits can be added or removed from either end of a number, significantly changing its value. For example, "123" can be altered to "1234" or "23," leading to misinterpretations that can have serious consequences.
- **Intentional Sabotage:** In contexts where malicious intent is present, the ease of altering traditional numerals makes them susceptible to sabotage. For instance, a

shipment label could be deliberately changed to redirect goods, or inventory numbers could be falsified to mask theft.

- **Accidental Errors:** Even without malicious intent, accidental alterations can occur. Smudges, partial erasures, or poor handwriting can easily transform one numeral into another, leading to unintended and potentially harmful misinterpretations.

These vulnerabilities are particularly problematic in scenarios like:

- **Secure Logistics:** Where accurate tracking and identification of goods are crucial to prevent theft or misdirection. Altered numbers can disrupt supply chains and compromise security.
- **Financial Transactions:** Accurate record-keeping is essential to prevent fraud. Modified numbers can lead to accounting errors and financial discrepancies.
- **Inventory Management:** Where precise counts are necessary for effective management. Altered numbers can result in shortages, overstocking, and logistical errors.

The combination of orientation dependence and vulnerability to alteration significantly undermines the reliability of traditional numbering systems in many critical applications. Therefore, there is a clear and pressing need for a numbering system that is unambiguous regardless of orientation and robust against accidental and deliberate alteration.

## Solution Overview

Space Ordinals are a solution to the problem of numerical ambiguity in challenging environments, such as space or virtual reality, where traditional numbering systems face issues due to orientation dependence and vulnerability to alteration.

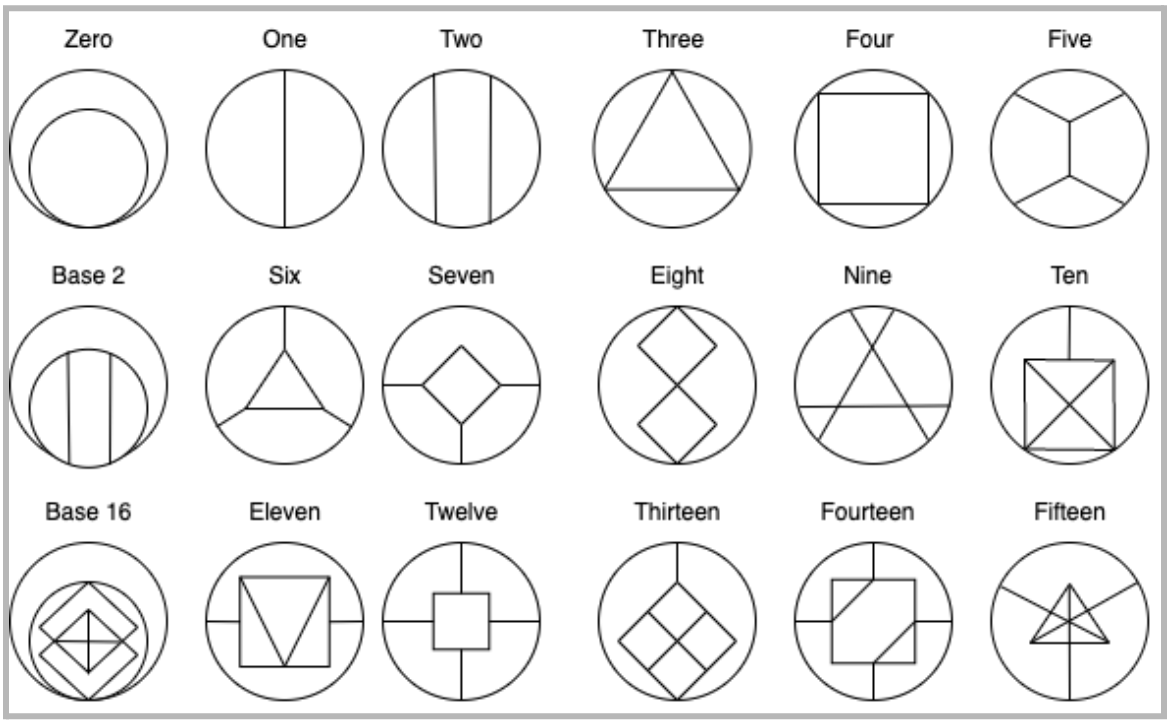


*Figure 1. An Early Version of Space Ordinals including Symbols for Base 2 and 16 numbers*

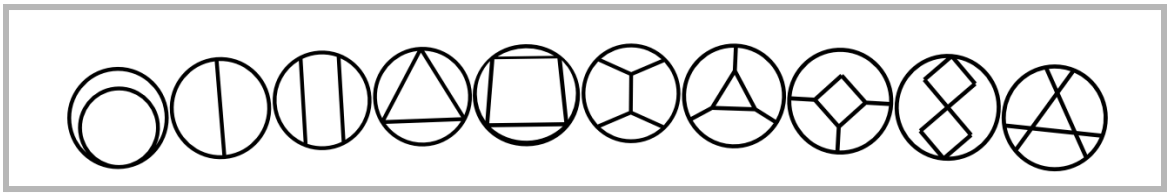

*Figure 2. Current Base 10 Space Ordinals 0-9 Used in Board Game Design*

Space Ordinals uses a circular pendant style with unique geometric patterns. These symbols are intuitive, robust against defacement, and readable regardless of orientation.

This system addresses the problem by providing symbols that:

- **Are not dependent on a fixed orientation:** This solves the issue of misreading numbers when rotated in zero-gravity or virtual environments.
- **Are robust and resistant to defacement:** This reduces the risk of misinterpretation due to damage or poor visibility, and makes deliberate alteration more difficult.
- **Are intuitive:** This ensures easy learning and use across various applications and potentially for interspecies communication.

Space Ordinals use these specially designed symbols to ensure clarity and precision in communication, where traditional numbers might lead to errors and confusion.

## Implementation

Each Space Ordinal digit of a number in everyday use is outlined by a perfect circle of the same size and thickness as all the other digits. This circle provides an explicit reference for detecting and correcting occlusions, defacements, and distortions.

Inside this circle is a unique geometric design containing several straight line segments whose quantity is equal to the value of the digit. The zero symbol has no line segments but includes a slightly offset smaller circle connected to the outer circle. The progression of complexity and count of lines as digits move from zero to nine makes the value of the symbols intuitive regardless of language or cultural background.

The line segments are purposefully constructed to make the addition or deletion of line segments apparent and will not transform one symbol into another.

In artistic expressions and specific constrained environments, the digits' relationship to each other is flexible. In robust applications, their relationship is well defined.

Within a single multi-digit number:

- Digits must touch, not overlap, or be separated by more than their symbol's radius unless connected by a line segment or other ornamentation that disallows the insertion of another digit. One or more symbol diameters should separate adjacent numbers.

- Digits should be arranged in a string or pattern with obvious adjacent digits. Usually, this is a straight line but can be a curve, circle, or other shape.
- Except for the first and last digit, the digits should not be rotated relative to the adjacent digits.
- The most significant digit should be rotated 45 degrees.
- The least significant digit should be rotated 90 degrees.

To encourage the adoption of Space Ordinals:

- The symbol design is freely available under one of the most permissive Creative Commons Licences (CC-BY) to encourage the adoption of Space Ordinals.
- Font packages are available to assist designers in incorporating Space Ordinals into their work.
- A book describing additional use cases and best practices for more complex usage is in the works.
- “A Space Ordinals: The Board Game” is being prepared for release so that people of all ages and backgrounds can experience the advantages and gain practice using Space Ordinals.
- A generic term, “Universal Numbers,” is proposed as a neutral term for this class of symbols, should other designers wish to invent another symbology with similar goals, and don’t want to be constrained by the Space Ordinals design language.

## Conclusion

Space Ordinals offer a vital solution to the inherent limitations of traditional numbering systems in non-standard environments like space and virtual reality. By addressing the issues of orientation dependence and vulnerability to alteration with an intuitive, robust, and universally readable symbol system, Space Ordinals ensure clear and precise communication where traditional numbers might fail. Space Ordinals' unique geometric patterns and design principles suit diverse applications, from critical space operations to engaging board games and potentially interspecies communication. Adopting non-ambiguous numbering systems like Space Ordinals becomes beneficial and essential as we expand our reach beyond Earth and delve deeper into virtual realms. We encourage designers, engineers, educators, and innovators across all fields to explore and implement Space Ordinals, paving the way for more reliable and efficient communication in the evolving landscapes of the future. The provision of open-source designs, font packages, and educational resources ensures that Space Ordinals can be readily adopted and integrated into a wide range of applications. By embracing Universal Numbers, we can provide clarity and accuracy in an increasingly complex and boundary-expanding world.

## About the Author / Organization

**William "Bud" Nail III** is President of Technological Services Company and a recognized contributor to advanced aerospace engineering and product development. His company works with a number of public and private organizations, including NASA, to produce technologies not available off the shelf. In 2014, NASA presented TSC with its SSC Small Business Subcontractor of the Year Award. He is a former NASA employee (1987- 2001) and awardee of NASA's Highest Engineering Award, NASA's Manned Flight Awareness Honoree Award, and recognized as an inventor of a technology patented by NASA. He is the co-author of several aerospace industry papers, and his research was covered in several industry news publications.

He has spent decades developing young engineers and other professionals through mentorships and advancing new technologies used in Rocket Propulsion Testing, Industrial Controls, and Information Technologies.

## Credits

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