The Growing Clutter in Earth's Orbit

Report on the visualization of space debris in Earth's orbit

Rihards Zeps

Data Studio – Final Assignment May 6, 2025

Abstract

This report integrates five bespoke visualizations—(1) payload responsibility by country, (2) satellites vs. debris overlap, (3) debris distribution across LEO/MEO/GEO, (4) annual payload vs. other launches, and (5) historical debris events—with foundational principles from our Data Studio lectures. By applying the ASK–EXPLORE– DISTILL–TELL storytelling arc, the DIKW pyramid, Ware's three-stage perceptual model, Koponen & Hildén's visual-variables hierarchy, Tufte's data-ink ratio, this work demonstrates both theoretical understanding and practical application toward sustainable orbital policy.

Contents

Introduction

Since Sputnik's 1957 launch, Earth's near-space environment has transformed from a few exploratory payloads to a congested orbital ecosystem of operational satellites and hazardous debris. The purpose of this report is to demonstrate not only what was done extracting and visualizing GCAT launch data but also why, using correct terminology and design justification per the Dataviz Lectures contents.

1 Application to the Space-Debris Case

1.1 Data Source & Classification

Data were drawn from the european space agency website and Jonathan McDowell's General Catalogue of Artificial Space Objects (GCAT), containing 24886 launch records. Each entry was classified as Payload (satellites, probes, station modules) or Other (rocket stages, adapters, debris).

1.2 Narrative Flow & Figure Sequencing

Figure 1: Country responsibility by payload (ASK).

Figures 2–3: Satellite–debris overlap and debris by orbit zone (EXPLORE).

Figure 4: Annual payload vs. other stacked bar (DISTILL).

Figure 5: Timeline of debris events (TELL).

1.3 Design Decisions

Pre-attentive cues: Marker size in Figure 2 highlight debris density.

Position encoding: Years on the x-axis, bar heights on the y-axis in Figure 4 maximize ratio-scale precision.

Color palette: White text with white or gray–scale visuals against a black backdrop ensures readability and comprehension.

Minimal gridlines: Subtle dashed y-axis guide lines without clutter.

Typography: Arial Narrow 55–40pt body, 100–75pt headings.

2 Figure Gallery

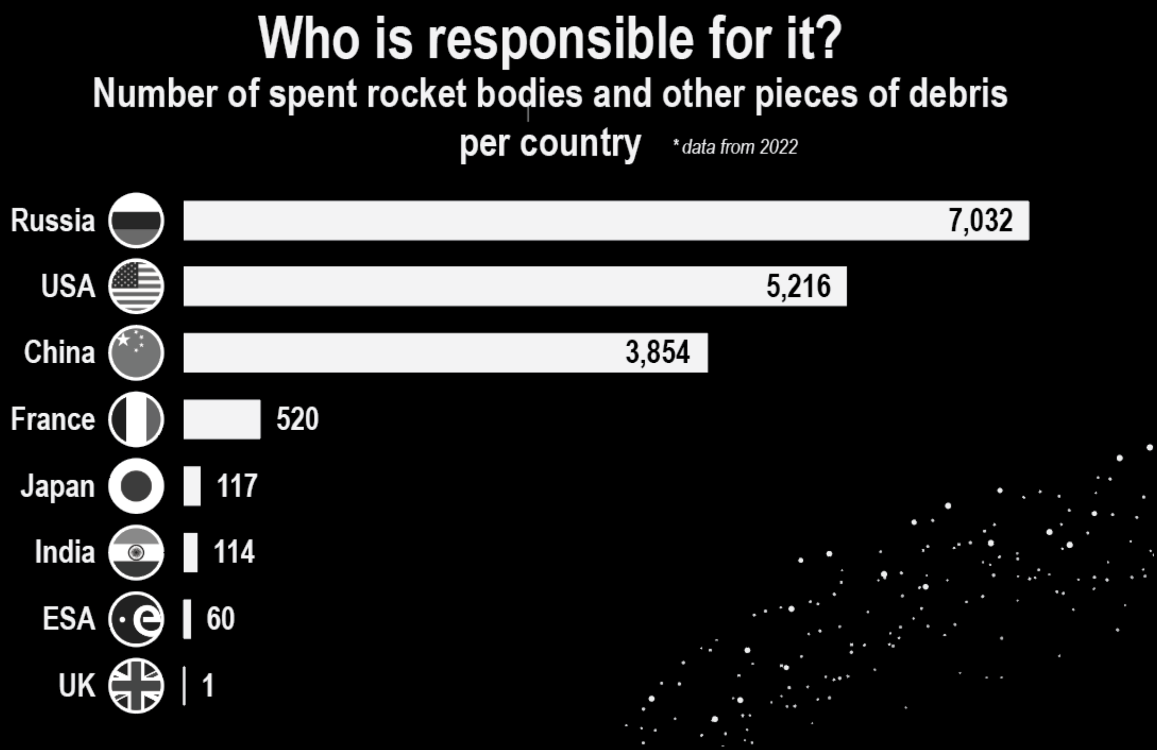

Figure 1: Country responsibility by payload launches. (2)

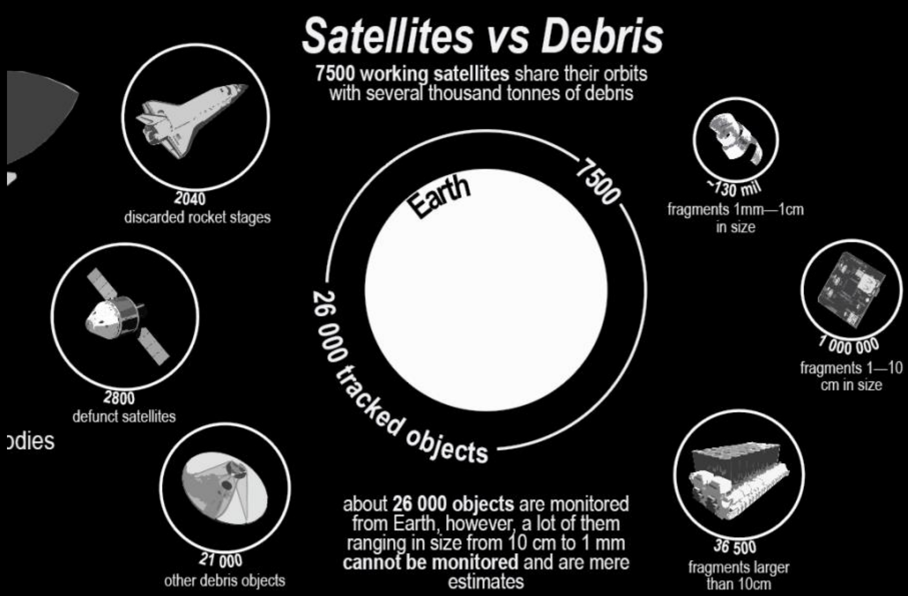

Figure 2: Working satellites vs. debris overlap, encoded by marker size. (2)

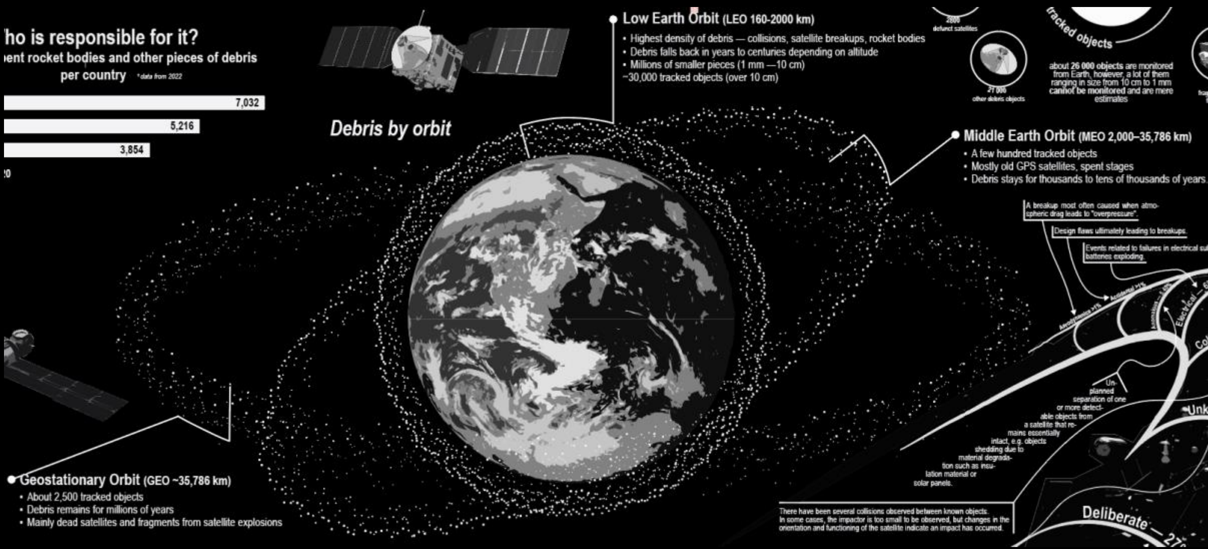

Figure 3: Debris distribution across orbit zones: LEO, MEO, GEO. [2]

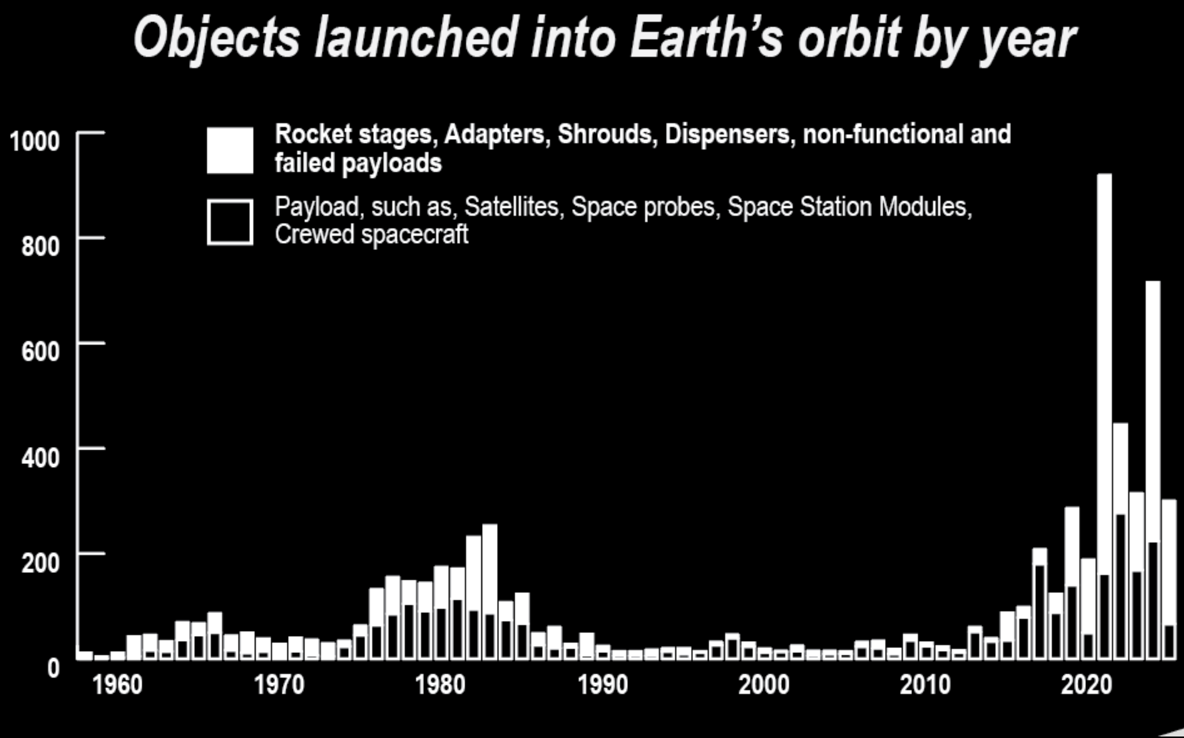

Figure 4: Annual launches: payload vs. other objects (1958–2025). [3]

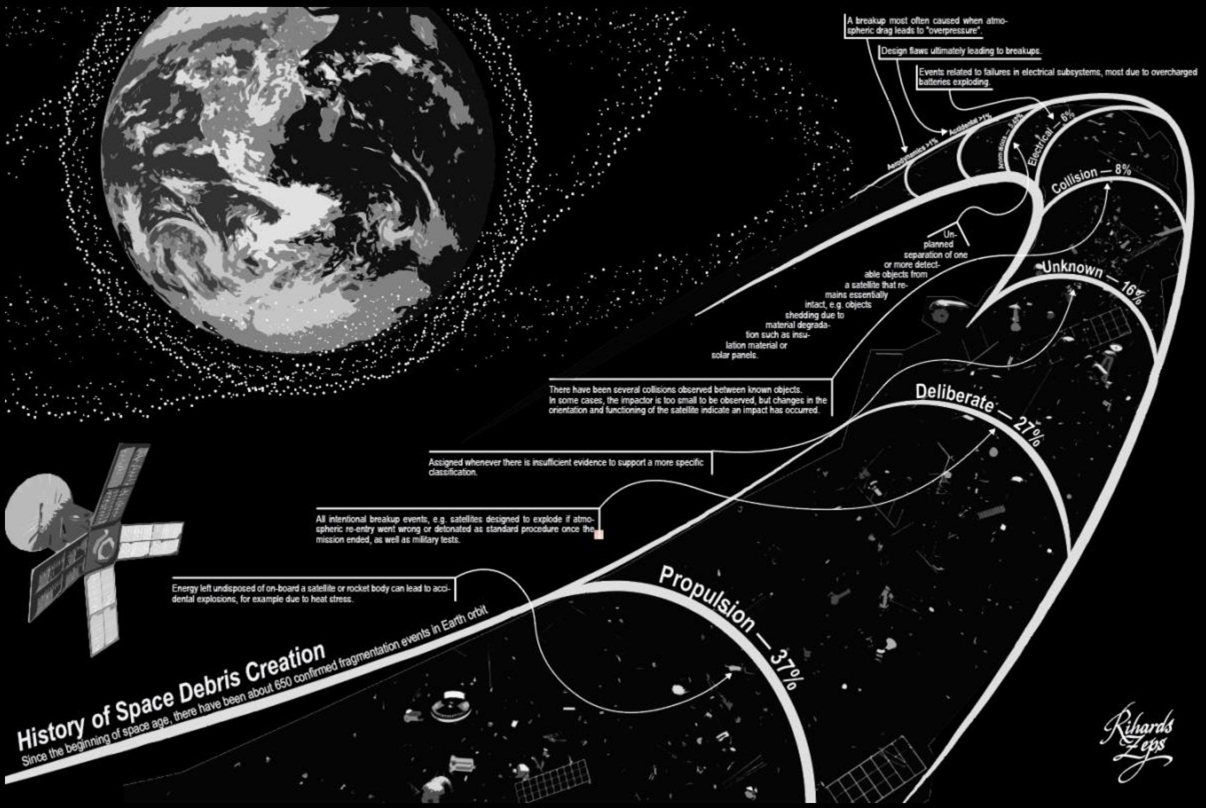

Figure 5: History of major space debris creation events. (2)

3 Integration of Lecture Concepts

This section demonstrates how core lessons from our Data Studio lectures were directly applied to the design and narrative of the space-debris visualizations.

3.1 ASK–EXPLORE–DISTILL–TELL Narrative Arc

Effective data stories frame a question (ASK), examine the data (EXPLORE), highlight insights (DISTILL), and deliver conclusions (TELL).

ASK: The Introduction poses the problem of exponential growth in payloads and debris since Sputnik (1957).

EXPLORE: Figures 1–3 enable viewers to investigate global responsibility, satellite–debris overlap, and orbit-zone distribution.

DISTILL: Figure 4's linear stacked-bar chart condenses yearly launch counts to reveal the post-2015 surge.

TELL: Figure 5's fragmentation events culminates in policy recommendations for debris mitigation.

3.2 DIKW Pyramid

The DIKW model transforms raw Data into Information, then into Knowledge, and finally into Wisdom that informs action.

Data: 24,886 launch records from GCAT.

Information: Visualizations (Figures 1–5).

Knowledge: Design rationales (color, scale, typography).

Wisdom: The conclusion's call to enforce sustainable orbital practices.

3.3 Visual-Variables Precision Hierarchy

Position along a common axis is the most accurate visual encoding, followed by length, angle, and then color hue; area and volume are the least precise.

Position: Years on the x-axis and bar heights on the y-axis in Figure 4.

Hue: Black for payload vs. White for other objects in Figure 4.

Avoided Encodings: No area-based symbol sizing to prevent misinterpretation.

3.4 Typography & Legibility

Arial Narrow between 40–55 pt for body text and 70–100 pt for headings ensure readability; contrast and hierarchy guide attention on large A2–A0 format.

Body Text: Arial Narrow 40–55 pt

Headings: Arial Narrow Bold 70–100 pt

3.5 Data-Ink Ratio & Minimalism

Tufte's principle advocates maximizing the ratio of data-ink to non-data-ink remove non-essential decorations so "above all else, show the data".

Gridlines: Only subtle dashed lines on the y-axis.

Graphics: Flat shapes, no 3D effects or heavy borders.

4 Key Insights

Payload Surge: Post-2015 mega-constellation deployments (e.g. Starlink) have driven payload counts to record highs. (Figure 4)

Debris Hazard: The "Other" category highlights accelerating accumulation of non-functional objects, elevating collision risk. (Figures 2,4,5)

Policy Call: These visual narratives support international debris-mitigation standards and sustainable launch practices.

5 Conclusion

This report not only presents precise GCAT data but also justifies every design decision in the terminology of the Data Studio course demonstrating that effective visualization is a blend of storytelling, visual perception science, precision encoding, minimal aesthetics, and typographic clarity. It also shows the data sources and references for each figure.

6 References

1) AM00CV29-3002 Data studio 9.1.2025-14.5.2025 Dataviz lectures
2) https://www.esa.int
3) https://planet4589.org/space/gcat/