NATE

THE COMMUNICATIONS INFRASTRUCTURE
CONTRACTORS ASSOCIATION

DRONE MAPPINGS
IN THE TELECOMMUNICATIONS INDUSTRY

A Study on Data Accuracy and Industry Applications – Past, Present, and Future

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UAS Data Modeling and Tower Mapping
Assessing Data Accuracy and Use Cases Enabled as Defined by ANSI/TIA 222-H

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CHAPTER I

INTRODUCTION TO UAS DATA CAPTURE AND DATA MODELING

For the better part of the last decade, an increased use of Small Unmanned Aircraft Systems ("UAS"), or drones, in the telecommunications industry has allowed stakeholders from across the supply chain to explore new approaches to analytics throughout asset life cycles. The ability of a UAS to capture comprehensive visual data of tower assets has made it a valuable tool for the industry allowing teams to augment workflows, reduce redundant site visits, and maximize the value of each touchpoint on antenna supporting structures.

In 2021, it is estimated that the telecommunications industry conducted more than 55,000 UAS flights domestically. The majority of these flights on antenna supporting structures yielded raw, 2D image data that was then processed using photogrammetry technology to create interactive 3D models, or "Digital Twins." UAS flights and Digital Twins, as a concept, are almost certainly one of the most transformative solutions the industry has seen in decades. As adoption increases and new use cases are explored, it is the position of the NATE UAS Committee, and TR-14 Drones Ad Hoc group, that a greater understanding of data accuracy will further the application and level of trust in this data collection and analytics methodology.

The purpose of this NATE Whitepaper is to share with the reader the background of UAS based use cases, the capabilities and limitations of the technology, and the use cases they enable today as defined by the requirements of the ANSI/TIA 222-H Standard. The foregoing will then be analyzed in the context of the 2022 NATE UAS Expo findings with a consideration of how those results impact our current understanding of UAS applications in the telecommunications industry.

CHAPTER II

BACKGROUND FOR STUDY

As mentioned in the introduction, the catalyst for this Whitepaper and the research informing it has been the significant adoption of UAS technology over the past few years. This adoption has been driven in large part by the opportunities enabled by post flight analytics. The most popular of these offerings has been a 3D reconstruction of an asset, or Digital Twin.

3D modeling and Digital Twin technologies have become more prevalent across most commercial sectors over the past decade. Industries including, but not limited to, construction, mining, agriculture, real estate, and renewable energy all benefit from application of UAS based data in their daily operations. The key differentiator between UAS based operations in those industries vs. the telecommunication industry is the vertical nature of the telecommunication industry's assets. This unique aspect coupled with the variety of structures from poles to guyed towers creates an additional layer of complexity and challenge when collecting data and processing accurate models.

There are three primary variables required to generate a digital version of an antenna supporting structure whether it is a tower, rooftop, or water tank. Those variables are:

1. Hardware (UAS/Camera/Sensor)
2. Asset Specific Flight Pattern
3. Photogrammetry Software

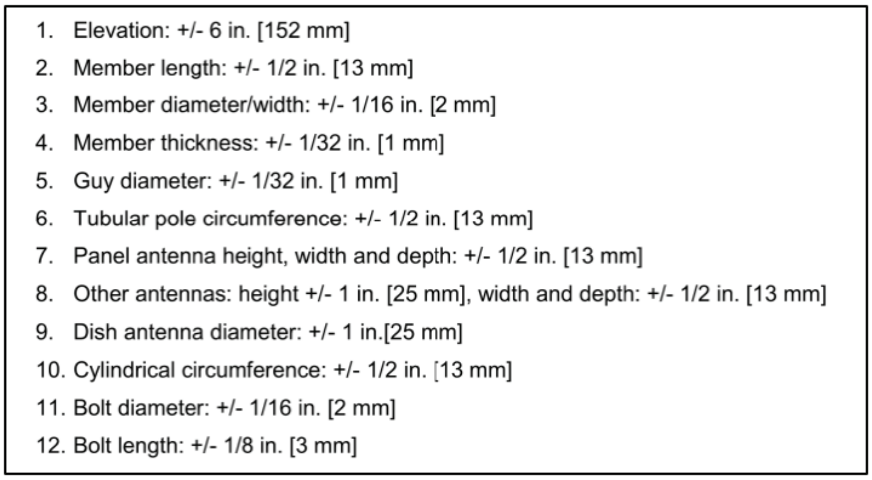
The research, and this Whitepaper, will focus primarily on Digital Twins as the end product rather than the hardware, workflows, or componentry leveraged to create them; the NATE UAS Committee and TIA Drones Ad Hoc plan to author a specific paper on those subjects in the future.

This research has been driven by discussions with End Users, Structure Owners, Contractors, and Engineering stakeholders interested in a validation study to better understand the dimensional accuracy of end deliverables provided by a UAS flight and corresponding data processing. Using the results of this study, the industry will be in a position to more deeply integrate UAS technologies into field-based workflows and asset analytics with similar confidence to traditional methods, while also properly understanding existing limitations.

The forum for the research and workflow simulation was the 2022 NATE UAS Expo hosted by Valmont Industries at their Valley, Nebraska manufacturing campus (the “Expo”). In the weeks leading up to the event, a simulation mount was installed on the research antenna supporting structure. Throughout the antenna mount structure there were simulated anomalies and deficiencies to be identified as part of the research.

In addition, a number of “Easter Eggs” were introduced into the simulation with known dimensions that could be compared against ANSI/TIA 222-H Annex J.2.3.1 Tolerances (Figure 1). These tolerances were a critical part of the research as they are required for the mapping of a structure and structure appurtenances. These Easter Eggs were fabricated and mounted to the antenna supporting structure prior to the Expo. The importance of this focus stems from the fact that these tolerances have served as a primary guide in the development of workflows, data collection methods, and end deliverables provided by telecommunication tower crews and engineering stakeholders for years.

For that reason, this Whitepaper will focus specifically on the capabilities and limitations of UAS and data processing technologies’ ability to meet these critical telecommunications industry requirements. Based on previous polling within the NATE UAS Committee and TIA Drones Ad Hoc, the assumption heading into the Expo was that the resulting data and research would yield accurate results in measurements with ½ inch or greater tolerances and challenges for deriving measurements in the 1/32 inch, 1/16 inch, and ⅛ inch tolerance ranges as required for specific measurements per ANSI/TIA 222-H.



1. Elevation: +/- 6 in. [152 mm]
2. Member length: +/- 1/2 in. [13 mm]
3. Member diameter/width: +/- 1/16 in. [2 mm]
4. Member thickness: +/- 1/32 in. [1 mm]
5. Guy diameter: +/- 1/32 in. [1 mm]
6. Tubular pole circumference: +/- 1/2 in. [13 mm]
7. Panel antenna height, width and depth: +/- 1/2 in. [13 mm]
8. Other antennas: height +/- 1 in. [25 mm], width and depth: +/- 1/2 in. [13 mm]
9. Dish antenna diameter: +/- 1 in.[25 mm]
10. Cylindrical circumference: +/- 1/2 in. [13 mm]
11. Bolt diameter: +/- 1/16 in. [2 mm]
12. Bolt length: +/- 1/8 in. [3 mm]

Figure 1 - UAS/TIA 222-H Annex J.2.3.1

UAS EXPO QUESTIONNAIRE

In addition to the simulated antenna supporting structure, a questionnaire was developed in collaboration with the Telecommunications Industry Foundation ("TIF"). Said questionnaire was issued to UAS Expo Exhibitors who participated in the Expo. The questionnaire was structured to assess two primary characteristics of the flight data:

1. Raw Visual Data Completeness -
While this aspect of the questionnaire will not be the focus of the Whitepaper, it was important to understand the completeness of visual data collected per flight. In relation to ANSI/TIA 222-H, UAS' have the potential to significantly enhance the completeness of a visual inspection when flights are conducted properly.

2. Data Model Dimensional Accuracy -
A detailed understanding of Digital Twins' capabilities and limitations will be a key driver of UAS adoption across the industry in the coming years. To assess this metric, a portion of the questionnaire was focused on the "Easter Eggs" mentioned above. (See Figures 2 & 4 below). Questionnaire results were compared against Easter Egg actuals to drive the core findings of this Whitepaper.

SITE SETUP AND CONDITIONS

1. Structure -
The antenna supporting structure used at the Expo was a Valmont pole structure located on their Valley, NE manufacturing facility's campus.

2. Appurtenances -
The research, focused primarily on dimensional tolerances, was structured to represent a very simple structure. There were three panel antennas and three radios fixed to a platform mount. The centerline AGL for the mount and associated equipment was roughly 25 feet. (Plans for future expos and associated research include greater complexity on larger structures. The strategy for this initial research engagement was focused on simplicity.)

3. Weather -
The data submitted was flown by participants who operated in full sun with light wind increasing throughout the course of the day. Data submitted below was collected between midday and late afternoon.

It should be noted that this simple configuration was used to create a base line for the understanding and that in future events more complex antenna mounts with lines and obstructions will be identified to address concerns with capturing information that is not always visible to a UAS.

CHAPTER III

COMPARISON OF KNOWN MEASUREMENTS VS. SUBMITTED RESULTS

To provide the most complete possible assessment of the telecommunications industry's UAS and data modeling capabilities, Expo organizers invited nine leading providers of UAS services to participate. Registered exhibitors represented at the Expo accounted for the vast majority of the data processing associated with the 55,000 flights and data models conducted in the U.S. telecommunications industry in 2021.

During the Expo, eight of the nine vendors present elected to participate in expo tower flights. Of those eight, five submitted questionnaires. Of those five, three elected to submit their results for the "Easter Egg" portion of the questionnaire. The chapter will focus on summarizing the findings from the submitted "Easter Eggs".

As mentioned in the background overview, the values and tolerances associated with the following simulation were structured in accordance with ANSI/TIA 222-H Annex J dimensional tolerances. Both Easter Egg mappings yielded similar conclusions that confirmed expectations prior to the expo:

1. All three exhibitors excelled in accurately measuring ½ inch and greater tolerance dimensions. There were seven measurements across the two Easter Eggs with ½ inch tolerances (primarily member lengths). For these measurements, 100% of the submissions across all three exhibitors were within tolerance.
2. On the other hand, there was a significantly lower accuracy percentage when measuring 1/16 inch tolerances associated with measurements such as member diameters and width. For these measurements, only 35% of the submitted measurements were within tolerance.

While these results did fall in line with pre-research assumptions, it is also a critical benchmark for the telecommunications industry to have set, for the first time, in a formalized research scenario. As detailed in later sections, these results will be shared with the TIA TR-14 Committee in an effort to have UAS included in the next Revision of the ANSI/TIA 222-H Standard, as well as allowing engineers to have confidence in cases where the data can currently be captured. Results and a brief summary are referenced on page 7 and 8:

Easter Egg #1

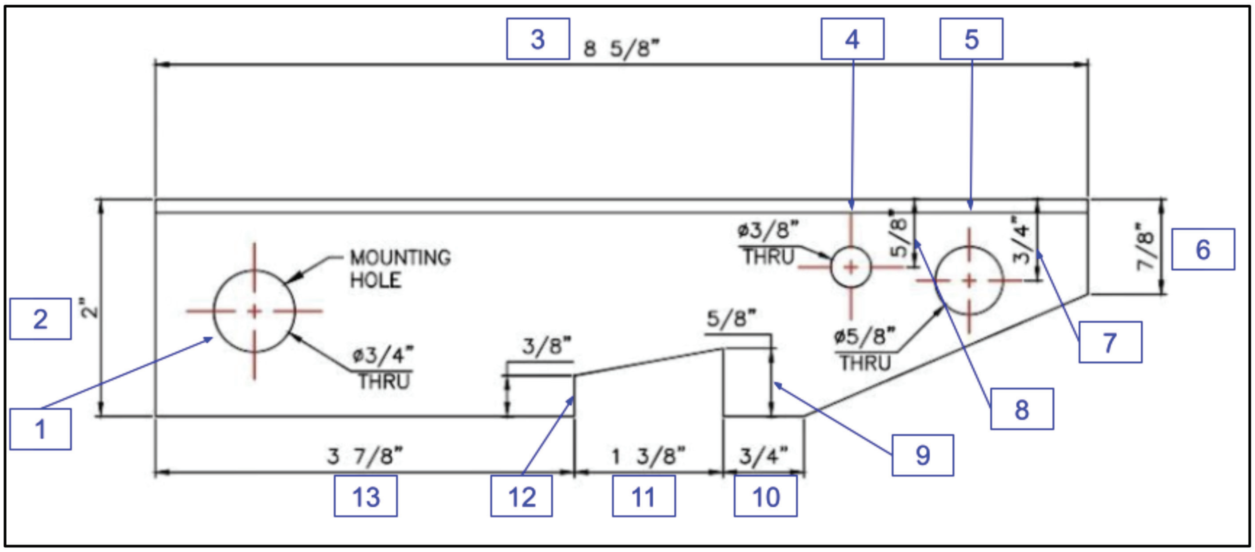
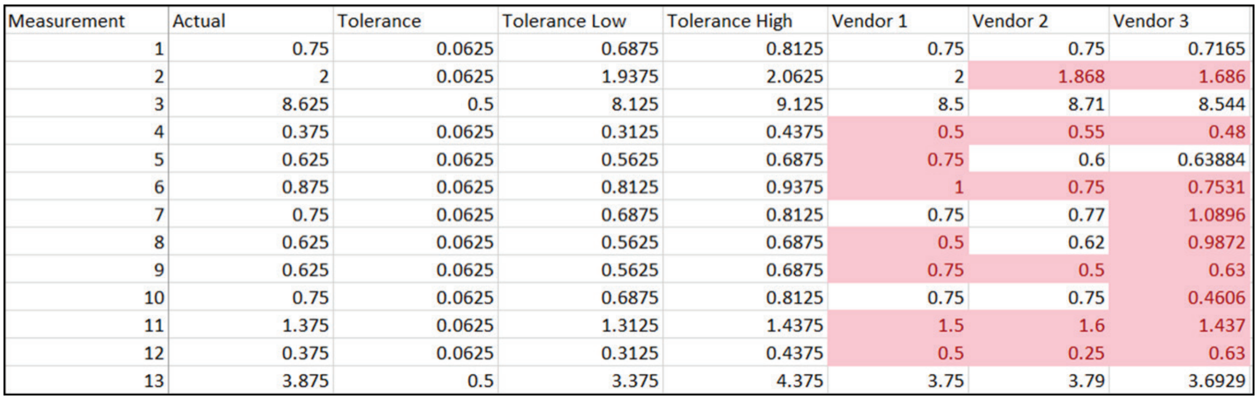


Figure 2 - Easter Egg #1



Measurement	Actual	Tolerance	Tolerance Low	Tolerance High	Vendor 1	Vendor 2	Vendor 3
1	0.75	0.0625	0.6875	0.8125	0.75	0.75	0.7165
2	2	0.0625	1.9375	2.0625	2	1.868	1.686
3	8.625	0.5	8.125	9.125	8.5	8.71	8.544
4	0.375	0.0625	0.3125	0.4375	0.5	0.55	0.48
5	0.625	0.0625	0.5625	0.6875	0.75	0.6	0.63884
6	0.875	0.0625	0.8125	0.9375	1	0.75	0.7531
7	0.75	0.0625	0.6875	0.8125	0.75	0.77	1.0896
8	0.625	0.0625	0.5625	0.6875	0.5	0.62	0.9872
9	0.625	0.0625	0.5625	0.6875	0.75	0.5	0.63
10	0.75	0.0625	0.6875	0.8125	0.75	0.75	0.4606
11	1.375	0.0625	1.3125	1.4375	1.5	1.6	1.437
12	0.375	0.0625	0.3125	0.4375	0.5	0.25	0.63
13	3.875	0.5	3.375	4.375	3.75	3.79	3.6929

Figure 3 - Easter Egg #1 Results

Easter Egg #2

Of the two Easter Eggs, results associated with #1 were on the whole less accurate. In addition to the irregularity of the notch cut into the bottom plane (measurements 9-12), there was a higher concentration of 1/16 inch tolerances creating a more challenging mapping scenario. Easter Egg #2 showed promising results and confirmed that the technology has matured to enable new approaches to gathering dimensional data on assets in scenarios geared towards ½ inch and greater tolerance measurements.

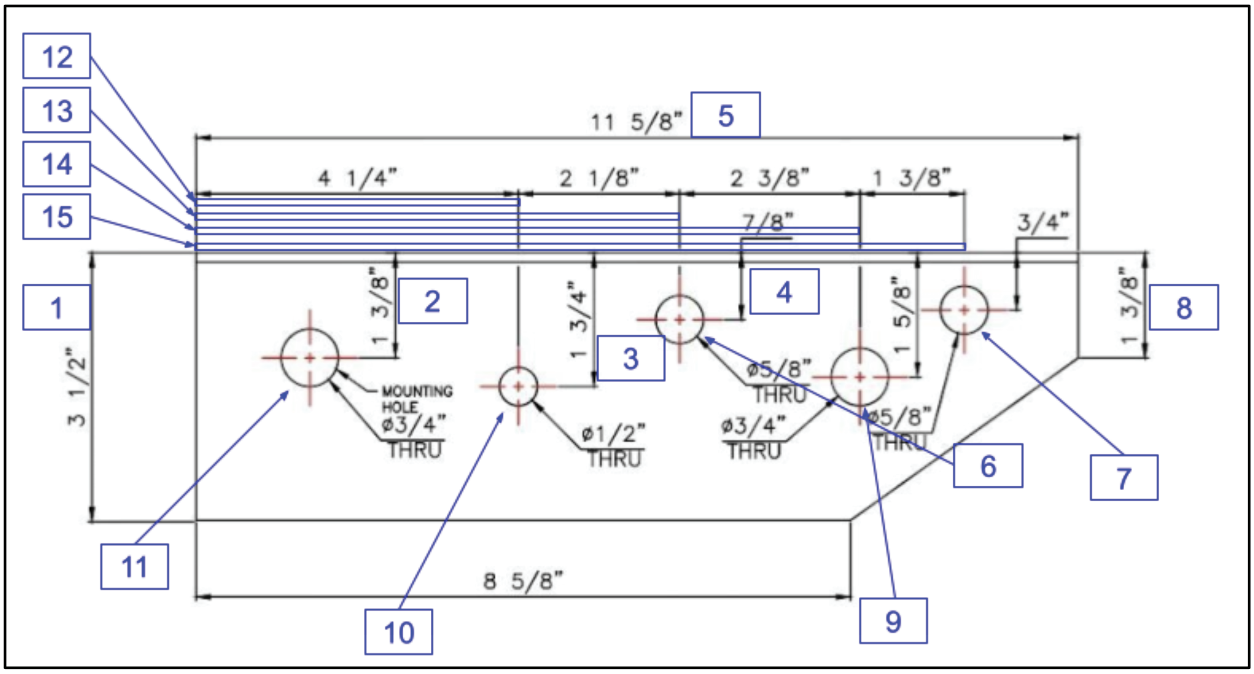
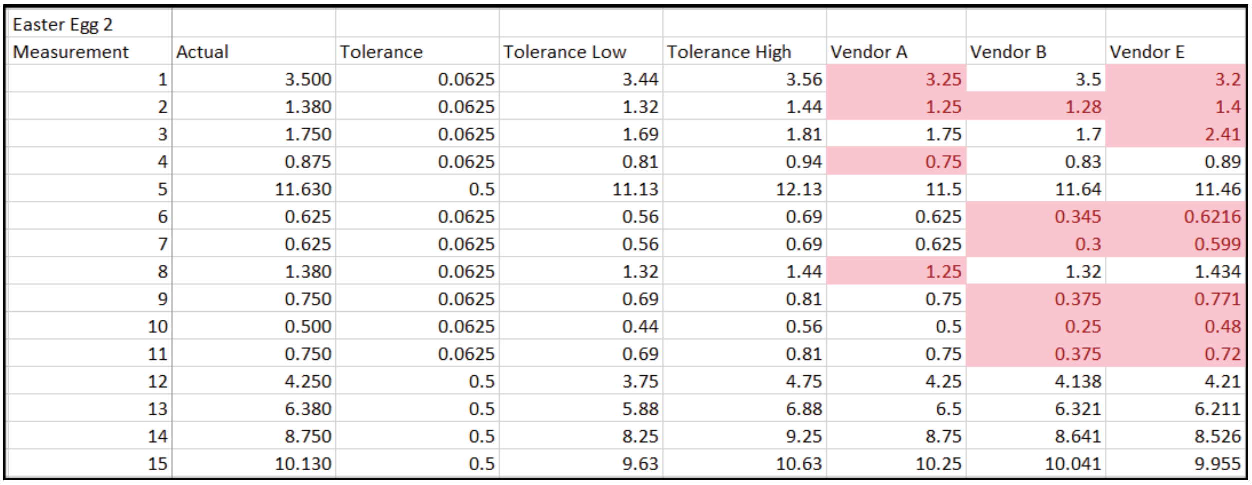


Figure 4 - Easter Egg #2



Easter Egg 2							
Measurement	Actual	Tolerance	Tolerance Low	Tolerance High	Vendor A	Vendor B	Vendor E
1	3.500	0.0625	3.44	3.56	3.25	3.5	3.2
2	1.380	0.0625	1.32	1.44	1.25	1.28	1.4
3	1.750	0.0625	1.69	1.81	1.75	1.7	2.41
4	0.875	0.0625	0.81	0.94	0.75	0.83	0.89
5	11.630	0.5	11.13	12.13	11.5	11.64	11.46
6	0.625	0.0625	0.56	0.69	0.625	0.345	0.6216
7	0.625	0.0625	0.56	0.69	0.625	0.3	0.599
8	1.380	0.0625	1.32	1.44	1.25	1.32	1.434
9	0.750	0.0625	0.69	0.81	0.75	0.375	0.771
10	0.500	0.0625	0.44	0.56	0.5	0.25	0.48
11	0.750	0.0625	0.69	0.81	0.75	0.375	0.72
12	4.250	0.5	3.75	4.75	4.25	4.138	4.21
13	6.380	0.5	5.88	6.88	6.5	6.321	6.211
14	8.750	0.5	8.25	9.25	8.75	8.641	8.526
15	10.130	0.5	9.63	10.63	10.25	10.041	9.955

Figure 5 - Easter Egg #2 Results

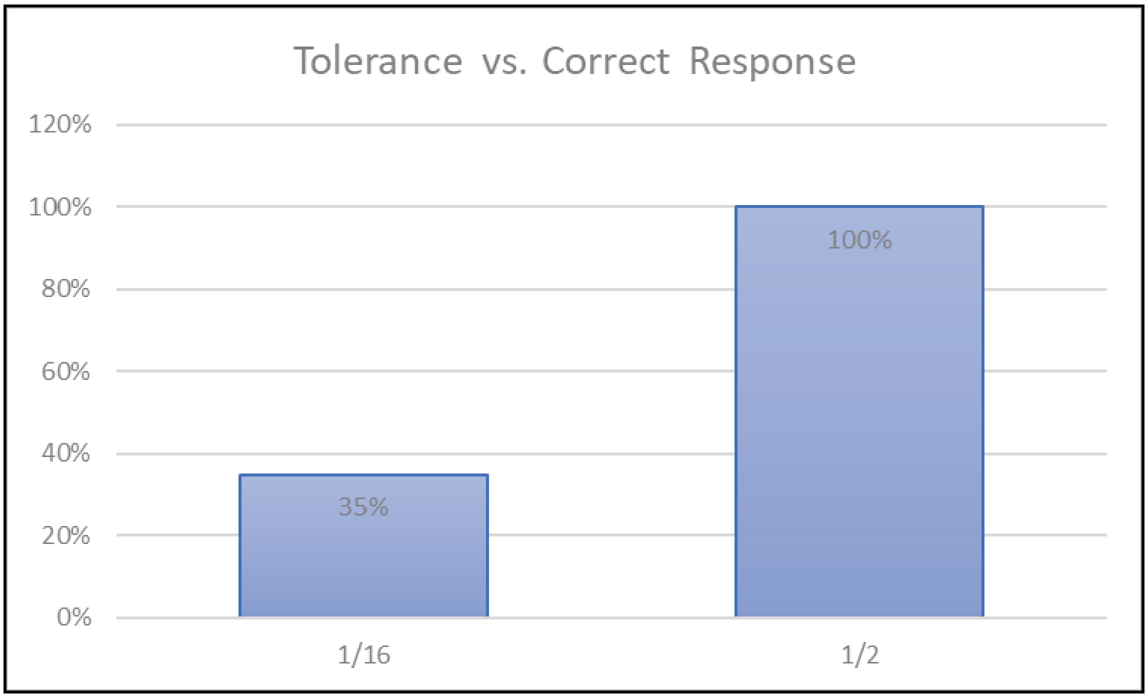


Figure 6 - Tolerance vs. Correct Response)

Disclaimer: It should be noted that the camera sensors leveraged to yield the above results were of higher quality and therefore yielded higher resolution data than those used for the majority of UAS flights in the telecommunications industry.

The average UAS flight in the U.S. market are typically conducted with a UAS carrying a 20 megapixel camera. The camera payloads leveraged by all exhibitors who submitted data for the research above were 60+ megapixel. Additionally, not all pixels are created equal. The quality and size of the individual pixels on the sensor play a role in accuracy and resolution of the final product.

The quality of a camera and sensor as well as the distance from the subject has a direct impact on the quality of the data that it produces. To bring greater clarity to the impact of camera quality, future studies conducted by the NATE UAS Committee and ANSI/TIA 222-H Drones Ad Hoc Committee will place a greater focus on the camera payload as a key research parameter.

CHAPTER IV

CURRENT STANDARDS APPLICATION

In the current revision of ANSI/TIA 222-H there is no mention of UAS technology. At the recent TR-14 Conference in October of 2022, the Drones Ad Hoc presented preliminary results from the Expo Questionnaire and proposed a framework for inclusion in the upcoming Revisions to the standard.

It was the suggestion of the Ad Hoc that UAS Technology be included as a recognized method of data acquisition to assist in inspections, mappings, and analyses of antenna supporting structures. The reasoning is as follows:

Impact to Annex J Workflows

As detailed in the results above, UAS technology coupled with proper data processing can extract measurements that fall within the dimensional tolerances of the existing standard. While the data cannot currently solve for all necessary measurements in the standard, it does offer the industry an opportunity to augment workflows by leveraging this new technology.

Precedence set by Annex K

There are multiple methodologies approved for guy tension measurements in ANSI/TIA 222-H Annex K. Annex K Section B - Indirect Methods details three tested and approved methodologies of measuring guy wire tensions including:

- The Pulse Method
- The Tangent Intercept Method
- The Shunt Type Dynamometer Method

As is the case with the Shunt Type Dynamometer Method, the effectiveness of any field-based data collection method relies on the proper maintenance and application of the tools and technology used in the process. UAS flights and the resulting data, when applied properly, can serve the industry in the same fashion: as a powerful tool leveraged across a number of different workflows and use cases to arrive at accurate and actionable data.

Highest and Best Use

Similar to Shunt Type Dynamometers, or any tool for that matter, there will be scenarios and use cases in the field when a UAS is not the proper tool for the job. In these scenarios, it is incumbent on the stakeholders to identify the tool and/or solution that best fits the realities of the asset, project objectives, and requirements of the analysis.

CHAPTER V

INDUSTRY APPLICATION

The past few years have seen significant improvements across all aspects of UAS technology. UAS hardware, camera sensor payloads, automated flight, and post flight analytics continue to advance daily.

Between in-house drone pilot teams and outsourced drone service providers (DSPs), it has never been easier to explore the use of the technology as part of a company's operations strategy or incorporate them into service offerings. Broader access to the technology has enabled the entire supply chain to engage and incorporate the data into their daily workflows.

When looking back at the Expo and its resulting data, it is easy to see how prolific the use of UAS technology could become in the years ahead. The following list details the potential cross functional impact of a single UAS flight and resulting data model.

End Users

- Line of Sight Surveys - Easily assess the surrounding area to ensure proper visibility between proposed and existing structures.
- Scoping/Sourcing - Enhance planning cycles with the ability to measure, maneuver, and simulate multiple scenarios.
- Closeout Reporting - Expedited post installation inspections.

Structure Owners

- Maintenance and Condition Assessments - Enhanced visual data to complement maintenance and condition managed programs.
- Vacancy Analytics - Complete visibility into the space available on a given structure and potential opportunity for optimization.
- Revenue Assurance/Lease Compliance - Detailed breakdown of an existing inventory list as it relates to tenant agreements.

Engineering

- Structure/Mount Mappings* - Measure existing structure and/or appurtenances as part of broader analysis. (In collaboration with End User and/or Structure Owner).
- Design - Iterate on asset mod/install/repair designs from digitally.
- Review for Post-Installation Inspection ("PII") and Post-Modification Inspection ("PMI")

* *Because UAS measurements are only reliably accurate within the closest 1/2", engineers performing analyses based off of UAS mappings will need to make certain assumptions on smaller dimensions, such as thickness of steel. They can utilize manufacturer knowledge and previous experience to identify known mounts and close the gaps as much as possible. However, assumptions will always lean conservative, so depending on the site, having the contractor gather specific measurements upon installation and reporting them back to the engineer will true up the data during the PII and PMI process.*

While applications like those mentioned above (among others) continue to expand across the supply chain, results from the 2021 NATE UAS Committee survey suggest that roughly 80% of the industry's drone flights that year were conducted by two major stakeholders: one network operator and one large tower company. Those numbers are significant and represent the beginning of strong adoption from some of the most critical end users in the market. However, they also suggest that the technology and its broader market adoption is still very much in its infancy.

Deeper integration into wireless infrastructure workflows and the expansion of the technology's use cases starts with broader adoption of the technology. The potential role of UAS technology will play in the industry over the next decade is incalculable. The objective behind research projects such as the Expo is to communicate current capabilities clearly, drive awareness of the opportunities they present, and create a catalyst for dialogue to promote advancement of the technology.

CHAPTER VI

INDUSTRY IMPACT AND OTHER CONSIDERATIONS

As we will undoubtedly see in the coming years, the use of UAS and the optimization of their data will forever change the industry's approach to asset lifecycle management. From vacancy analytics to post construction closeout reporting, UAS have the potential to drastically reduce the number of site visits required to enhance the reliability and capacity of a structure, understand trends and opportunities across a portfolio, and address them all with great precision.

At this early stage of adoption, it is hard to quantify the potential impact this technology will have on the existing workforce. However, the impact of UAS technology can be estimated by reviewing the UAS flights conducted domestically in 2021 by the telecommunications industry.

If the UAS flights conducted that year saved on average a single redundant site visit one could assume conservatively:

- ***1.5 Hours*** - time spent on site
- ***1 Hour*** - time spent summarizing site findings
- ***2.5 Hours*** - total time saved per site

Multiplied by 55,000 towers (2021 data), the time saved can be approximated to over 137,000 labor hours. Furthermore, when mobilization to and from site is considered, the saving could be in excess of 300,000 labor hours (assuming 1.5 hours each way to site)!

The NATE UAS Committee and TIA Drones Ad Hoc are currently finalizing industry surveys to understand with more granularity the rate of adoption, composition of the UAS user base, and targeted workflows and use cases of flights across the industry. Once surveys have been deployed and distilled, results will be published and shared with the industry.

CHAPTER VII

SUMMARY

UAS hardware, automated flight, image processing, and data analytics are transforming the way stakeholders across the telecommunications industry interact and work to design, deploy, and maintain critical wireless infrastructure.

While the technology has made amazing advancements in recent years, the research herein concludes that there are still certain dimensional tolerances that cannot reliably or consistently be derived from UAS operations and data processing alone. It should also be noted that if there is not a line of sight for the UAS to capture the data then there will need to be another method of verification. As it relates to the ANSI/TIA 222-H Standard, the research would suggest that, when conducted properly, UAS flights, data post processing, and the resulting Digital Twin can satisfy 7 of the 12 defined tolerances in Annex J when visible.

This would also suggest that there are a significant number of workflows throughout the service lifecycle of an antenna supporting structure that can confidently be complemented, augmented, or facilitated by UAS operations under the proper conditions. This is critical for the responsible party to understand the specific use case, limitations, and the deliverables expected.

Inclusion in the next revision of the ANSI/TIA 222-H Standard is a significant opportunity for the telecommunications industry and could act as one of the largest single catalysts for UAS adoption in the industry. It should be noted that many have already started to effectively utilize UAS for telecommunications work by setting proper expectations and deliverables. If managed properly, adoption across the existing workforce could also create a feedback loop that accelerates the development of industry specific solutions and significant efficiency gains at every layer of the supply chain.

Finally, it is critically important that we as an industry continue to collectively pursue a deeper understanding of the solutions and advanced technologies at our disposal. As an industry with an historically constrained labor market, we have an opportunity to be better stewards of our resources. Most critically: time.

AUTHORSHIP CONTRIBUTIONS

The Association would like to recognize the following individuals who volunteered their time and expertise to the development of this NATE Whitepaper. Without their dedication and commitment to the furtherance of greater understanding within the telecommunications industry, this NATE Whitepaper would not have been possible. These individuals made substantial contributions to the conception, design, research, and ultimate drafting of this NATE Whitepaper and were critically important to its intellectual and technical content.

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