



SMART CABLE LABELING DESIGN BASED ON NEAR FIELD COMMUNICATION AT THE DVOR/ILS LABORATORY OF MEDAN AVIATION POLYTECHNIC

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Abstrak

Pengembangan teknologi navigasi penerbangan membutuhkan sistem pendukung laboratorium yang efisien, mudah diakses, dan mampu mengurangi kesalahan identifikasi komponen. Laboratorium DVOR/ILS Politeknik Penerbangan Medan masih menggunakan label kabel konvensional yang memberikan informasi terbatas. Kondisi ini dapat mempersulit identifikasi kabel, terutama selama kegiatan praktikum, pemeliharaan, dan pemecahan masalah. Proyek akhir ini bertujuan untuk merancang dan mengimplementasikan sistem pelabelan kabel pintar berbasis NFC sebagai media identifikasi kabel digital. Sistem ini dirancang menggunakan Tag NFC NTAG213, smartphone berkemampuan NFC, aplikasi NFC Tools, situs web berbasis HTML dan CSS, dan GitHub Pages sebagai platform publikasi. Sistem ini diterapkan pada 50 kabel di Laboratorium DVOR/ILS. Setiap Tag NFC menyimpan alamat situs web yang berisi informasi kabel, termasuk nama kabel, fungsi, input, output, dan spesifikasi teknis. Hasil pengujian menunjukkan bahwa Tag NFC dapat dibaca pada jarak 0,5 cm hingga 4,0 cm, dengan jarak pembacaan rata-rata yang berhasil sebesar 2,25 cm. Waktu respons sistem rata-rata adalah 0,76 detik. Hasil ini menunjukkan bahwa sistem tersebut dapat mendukung identifikasi kabel yang lebih cepat, lebih praktis, dan lebih informatif.

Kata Kunci: Pelabelan Kabel Pintar, NFC, Tag NFC, Situs Web, DVOR/ILS

Abstract

The development of aviation navigation technology requires laboratory support systems that are efficient, accessible, and able to reduce component identification errors. The DVOR/ILS Laboratory of Medan Aviation Polytechnic still uses conventional cable labels that provide limited information. This condition can complicate cable identification, especially during practical activities, maintenance, and troubleshooting. This final project aims to design and implement an NFC-based smart cable labeling system as a digital cable identification medium. The system was designed using NTAG213 NFC Tags, an NFC-enabled smartphone, the NFC Tools application, an HTML and CSS-based website, and GitHub Pages as the publication platform. The system was applied to 50 cables in the DVOR/ILS Laboratory. Each NFC Tag stores a website address containing cable information, including cable name, function, input, output, and technical specifications. The test results show that the NFC Tag can be read at a distance of 0.5 cm to 4.0 cm, with an average successful reading distance of 2.25 cm. The average system response time is 0.76 seconds. These results indicate that the system can support faster, more practical, and more informative cable identification.

Keywords: *Smart Cable Labeling, NFC, NFC Tag, Website, DVOR/ILS*

INTRODUCTION

The increasingly rapid development of aviation navigation technology demands a reliable, integrated, and efficient support system, particularly in equipment management and maintenance (Transportation, 2017). This is in line with aviation safety standards set by the International Civil Aviation Organization (ICAO) through Annex 10: Aeronautical Telecommunications, which emphasizes that aviation navigation and communication systems must have a high level of reliability, accuracy, and continuity to ensure the safety of flight operations (Aktas et al., 2022). This standard requires that every component in the navigation system, including supporting devices and cable installations, can function optimally and be easily identified to minimize the risk of operational errors (Organization, 2018b).

The Doppler VHF Omnidirectional Range (DVOR) and Instrument Landing System (ILS) laboratories at the Medan Aviation Polytechnic are essential facilities used in practical activities to support students' understanding of air navigation systems. Therefore, facilitating component identification, particularly cable routing, is crucial (*Aviation Maintenance Technician-Airframe Handbook - Volume 1*, 2022).

Based on current conditions, the cable labeling system in the DVOR/ILS laboratory has been implemented using conventional methods, namely with physical labels in the form of writing or specific codes affixed to the cable. This method helps in the basic identification process, but still has quite significant limitations, especially in terms of the capacity of the information that can be conveyed (Hou et al., 2024). Conventional labels generally only contain simple information such as cable codes, so they are not able to present more detailed information, such as cable functions, inputs, outputs, technical specifications, and connection relationships between devices (Rodriguez Martinez, 2025).

Limited information on cable labels can potentially lead to errors in the identification process. This can lead to connection errors, navigation system disruptions, and even equipment damage. In an educational laboratory environment, this can also hinder the learning process and reduce students' understanding of the systems being studied (Angeloe et al., 2024). Furthermore, limited information complicates the identification process, especially for new users (Organization, 2022). During practical work, testing, and maintenance and troubleshooting, users must manually trace cable paths to understand the functions and connections between devices. This process takes longer and increases the risk of human error (Lee, 2025).

Along with the development of information technology, the use of digital-based systems has become one solution to overcome these problems. One technology that can be used is near field communication (NFC). According to (Ningsih et al., 2023)[7], NFC is a short-range wireless communication technology that enables fast and practical data exchange and can be used as a digital-based identification medium. This technology is widely used because of its ease of use and the speed of information access it offers. By utilizing NFC technology, information can be stored in digital form on a tag that can be accessed using devices such as smartphones (Akbar & Silaban, 2025).

RESEARCH METHOD

The research design used in this final project is the design science research method, which focuses on creating a system as a solution to an existing problem. The Design Science Research method in this study consists of several stages (Martinez-Valencia et al., 2021): problem identification, determining solution objectives, system design, implementation, and system evaluation. This method was chosen because it produces a product in the form of a website as a cable information medium integrated with NFC technology.

The term "design" is used in this study because the research focuses on the design process of a smart cable labeling system as a cable identification solution in the DVOR/ILS Laboratory.

The prototype created is an implementation of the system design to validate the system's function and performance before wider implementation (FAA, 2023).

The research was conducted by implementing a smart cable labeling system using available devices, namely a smartphone with NFC features, NFC tags as data storage media, and the NFC Tools application as a tool for reading and writing data. In addition, this system is also equipped with a website that functions as a data management center and displays cable information (Organization, 2023). The website is integrated with NFC tags, so that any data stored on the tag can be directed to a website page to display complete cable information through a scanning process using a smartphone. After the system was implemented, testing was conducted to determine the system's performance and effectiveness in its use in a laboratory environment. This testing included ease of reading cable information, data access speed, and the accuracy of the information displayed (Faizah & Widagdo, 2024).

The design of the tool in this study was carried out through several stages that illustrate the working process of a smart cable labeling system based on Near Field Communication (NFC). These stages include the process of recording cables, inputting cable information on the website, writing website links to NFC Tags, and installing NFC Tags on the cables that are the object of the study. The overall system design flow is shown in Figure 3.1.

The following is a block diagram of the tool design that illustrates the process of creating a website up to the upload stage to GitHub (Cahyadi et al., 2024).

In this study, NFC Tag reading distance testing was conducted to determine the effective scanning distance (Nur et al., 2024). Ten trials were conducted, varying the distance between the reader (smartphone) and the NFC Tag. Each trial was recorded based on the distance (cm) and whether the reading was successful or unsuccessful (Némethová & Zýka, 2024).

The testing technique in this study was carried out to determine the effective distance of NFC Tag reading. The test was carried out by bringing the smartphone close to the NFC Tag with a certain distance variation. Each trial was recorded based on the distance and success of the reading, and was carried out 10 times to obtain more accurate results. The data obtained were then analyzed to determine the effective distance of NFC Tag reading. This research was carried out at the DVOR/ILS Laboratory of the Medan Aviation Polytechnic 2026 until July 2026 (Pasandín & Pérez, 2021).

RESULTS AND DISCUSSION

This research resulted in a *near-field communication (NFC)* -based *smart cable labeling design* to support the cable identification process at the Medan Aviation Polytechnic's DVOR/ILS Laboratory. The system combines NFC tags, an NFC-enabled *smartphone*, the *NFC Tools application*, an HTML and CSS-based *website*, and the *GitHub Pages* service as a website publication medium (Gu et al., 2023).

The system works on a simple principle. An NFC tag stores the URL address of a *website*. When a user brings *their smartphone* close to the NFC tag attached to the cable, *the smartphone* reads the data and opens the cable information page. The *website* displays the cable name, function, inputs, outputs, and technical specifications. This way, the cable label serves not only as a physical marker but also as access to more comprehensive digital information.

Smart cable labeling system implementation results

The system implementation is based on the design in Chapter 3. The system design focuses on 50 cables located in the DVOR/ILS Laboratory. Each cable is given a digital identity via an NFC Tag.

All the main components can be connected according to their respective functions. *The smartphone* acts as the active device (Organization, 2018a). The NFC tag serves as passive storage. The website serves as an information center. The integration of these three components makes the cable identification process more convenient because users simply scan the attached tag (Halim et al., 2025).

Results of Making a Cable Information Website

The website serves as the primary medium for displaying cable information. The website's structure is designed to be simple so users can quickly access the information on their *smartphone screens*. The website displays the main page, a cable list, and a cable detail page. The cable detail page contains data relevant to identification needs at the DVOR/ILS Laboratory (Google, 2023).

The website's results demonstrate that cable information can be presented more comprehensively than conventional labels. Physical labels typically only contain short codes. Websites can display more information without the limitations of label size. This helps students and technicians understand cable functions and the input and output connections between devices (Jaffar et al., 2021).

The cable information website was created to store and present information about cable identification in the DVOR/ILS system. This website connects to NFC tags via a URL stored on each tag. When an NFC tag is scanned using a smartphone, the user is directed to the cable information page corresponding to the scanned tag's identity.

Based on Figure 4.1, the website successfully displays carrier cable information on the DVOR system. The information displayed includes the cable's function as a carrier signal carrier from the DVOR transmitter to the antenna system, input, output, operating frequency, and additional information. This display indicates that the NFC Tag has been connected to the appropriate cable information page (Khatib Sulaiman & Yogyakarta, 2023).

Results of Inputting Website URL into NFC Tag

Entering a website URL into an NFC Tag is done using the *NFC Tools application*. This step aims to save the website address to the NFC Tag so that the cable information can be accessed directly via an NFC-enabled *smartphone*. The entered URL is the address of a website page published on GitHub Pages. The page contains cable information such as the cable name, function, input, output, and technical specifications.

The first step is to open the *NFC Tools application*, then select the *Write* and *Add a record* menu to add data to be stored on the NFC Tag (FYI, 2023).

Add a record menu, the selected data type is URL/URI because the cable information is stored as a website address. Selecting URL/URI allows the smartphone to open the cable information page when the NFC Tag is scanned.

After selecting the URL/URI data type, enter the website address in the provided field. The URL will be matched to the information page for the cable that will be connected to the NFC Tag. The URL input process is shown in Figure 4.4.

The next step is to select the *Write command* to write the URL to the NFC Tag. Once the URL is entered, select the OK button to save the data before tapping.

After the command is selected, the *NFC Tools application* displays the Approach an NFC Tag instructions. The process of writing a URL to an NFC Tag is shown in Figure 4.5.

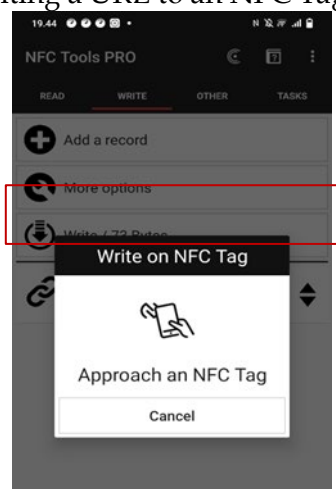


Figure 1. Process of Writing Website URL to NFC Tag

If the write process is successful, the *NFC Tools application* displays a *Write complete notification*. This notification indicates that the website URL has been successfully saved to the NFC Tag and can be used for the cable identification process shown in Figure 4.6.

Based on the input results, the NFC Tag successfully saved the URL of a website page containing cable information. When the NFC Tag is scanned using a *smartphone*, the system will open the website page according to the entered URL. This result indicates that the integration process between the website and the NFC Tag has been successful. Thus, the NFC Tag can function as a connecting medium between physical cable labels and digital cable information (Ningsih et al., 2023).

Results of Implementing NFC Tag Scanning on Cables

After the website URL has been successfully entered into the NFC Tag, the next step is to attach the NFC Tag to the designated cable. The NFC Tag is attached according to the cable's identity so that each tag can be directed to the correct cable information page. This step aims to ensure that the NFC Tag can be used as a digital label on cables in the DVOR/ILS Laboratory (Purba et al., 2023). After the NFC Tag is attached to the cable, the scanning process is carried out using a *smartphone* that supports the NFC feature. The *smartphone* is brought close to the NFC Tag at an appropriate distance until the device reads the data stored on the tag. At this stage, the NFC Tag functions as a connecting medium between the physical label on the cable and the cable information website page (Nugroho & Barkah, 2023).



Figure 2. NFC Tag Scanning Process Using a Smartphone

When the NFC Tag is successfully read, the *smartphone* will receive data in the form of a previously saved website URL. This URL will then direct the user to a website page containing cable information. This process demonstrates that the integration between the NFC Tag and the website is working properly.

Based on Figure 4.9, the *smartphone* successfully reads the URL data stored on the NFC Tag. The URL corresponds to the cable information page previously entered using the *NFC Tools app*. Once the link is selected, the browser will open a website displaying the cable information corresponding to the scanned NFC Tag.

After successfully reading the NFC Tag, a cable information website page opens in your *smartphone's browser*. The page displays the cable name, function, input, output, and technical specifications (Rahman, 2020).

Based on Figure 4.10, the NFC Tag scanning process successfully directs the *smartphone* to the SIN USB Cable information website page. The page displays structured cable data, including cable name, function, input, output, frequency, and description. This information makes it easier for users to understand the function and connection of the cable without having to manually trace the cable path. This shows that the NFC-based *smart cable labeling system* can be used as a digital cable identification medium. This system makes it easier for users to obtain cable information quickly, practically, and structured in practical activities, *maintenance*, and troubleshooting in the DVOR/ILS Laboratory.

NFC Tag Reading Distance Test Results

NFC Tag reading distance testing is performed to determine the effective distance between *the smartphone* and the NFC Tag during the scanning process. This testing is performed because NFC operates at close range, so the position and distance between *the smartphone* and the NFC Tag significantly affect the success of data reading.

In this test, the NFC Tag is placed in a fixed position, then *the smartphone* is gradually brought closer according to the predetermined distance. A ruler is used as a measuring tool to determine the distance between *the smartphone* and the NFC Tag. Each test distance is observed based on *the smartphone's* success in reading the NFC Tag and opening the cable information website page. Documentation of the NFC Tag reading distance test at a distance of 2 cm is shown in (TIA, 2012). Based on Figure 4.11, the NFC Tag was successfully read at a distance of 2 cm. This is indicated by the opening of the cable information website page on the *smartphone screen*. At this distance, the "Cable Carrier" website page can be displayed directly after *the smartphone* is brought close to the NFC Tag. This condition indicates that the distance of 2 cm is included in the stable reading range. The results of the NFC Tag reading distance test are shown in Table 4.3.

Table 1. NFC Tag Reading Distance Test Results

The first attempt	Distance (cm)	Results
1	0.5	Succeed
2	1.0	Succeed
3	1.5	Succeed
4	2.0	Succeed
5	2.5	Succeed
6	3.0	Succeed
7	3.5	Succeed
8	4.0	Succeed
9	4.5	Fail
10	5.0	Fail

The average NFC tag reading distance is calculated based on the distance successfully read by *the smartphone*. Distances that fail to be read are not included in the average calculation because they do not indicate a successful reading by the system.

The average reading distance formula is as follows:

$$\frac{0,5 + 1,0 + 1,5 + 2,0 + 2,5 + 3,0 + 3,5 + 4,0}{8} = 2,25 \text{ cm}$$

So, the average successful NFC Tag reading distance is 2.25 cm.

Based on the test results in Table 4.3, the NFC Tag was successfully read at a distance of 0.5 cm to 4.0 cm. The total successful reading distance was 18 cm from 8 successful trials, resulting in an average successful reading distance of 2.25 cm. These results indicate that the NFC-based *smart cable labeling system* can work well at close range, especially in the range of 0.5 cm to 3.0 cm, which indicates stable reading.

System Response Time Test Results

System response time testing was conducted to determine the system's speed in displaying the cable information page after the NFC Tag was scanned using *a smartphone*. Response time was calculated from the moment *the smartphone* read the NFC Tag until the cable information website page successfully appeared on the *smartphone screen* (Want, 2011).

In this test, the NFC Tag is placed in a fixed position, then *the smartphone* is brought close to the NFC Tag at a stable reading distance. Time measurements are performed using a stopwatch to record the system's response time. The stopwatch starts when *the smartphone* is brought close to the NFC Tag and stops when the cable information page successfully opens on *the smartphone* (Tuturoong et al., 2024).

Based on Figure 4.12, the response time test was conducted 10 times. Each trial showed a different time, but all trials successfully opened the cable information page. This indicates that the NFC Tag can be read by *the smartphone* and the system is able to direct the user to the appropriate website page. The results of the system response time test are shown in Table 4.4.

Table 2. System Response Time Test Results

The first attempt	Response Time (seconds)	Results
1	0.96	Succeed
2	1.66	Succeed
3	1.00	Succeed
4	0.61	Succeed
5	0.60	Succeed
6	0.59	Succeed
7	0.53	Succeed
8	0.45	Succeed
9	0.48	Succeed
10	0.76	Succeed

Source: Author, 2026

$$\frac{0,96 + 1,66 + 1,00 + 0,61 + 0,60 + 0,59 + 0,53 + 0,45 + 0,48 + 0,76}{10} = 0,76$$

So, the average system response time is 0.764 seconds.

Based on the test results in Table 4.4, all experiments showed successful results. The total response time from 10 experiments was 7.64 seconds, resulting in an average response time of 0.76 seconds. These results indicate that the NFC-based *smart cable labeling system* is capable of displaying cable information pages quickly after the NFC Tag is scanned using a *smartphone*.

All test results fell below the 2.5-second time limit used as a good indicator for the Largest Contentful Paint (LCP) indicator. This indicates the system can quickly display cable information after scanning the NFC tag.

Implementation Results of Each NFC Tag

smart cable labeling system implementation, testing was conducted on 50 NFC Tags that had been installed on cables in the DVOR/ILS Laboratory of the Medan Aviation Polytechnic. The testing was carried out in three stages: writing the website URL into the NFC Tag, reading the NFC Tag using an NFC-enabled smartphone, and checking the conformity of the cable information displayed on the website. The percentage of implementation success is calculated using the following equation:

Calculation formula:

$$\text{Success Percentage} = \frac{\text{jumlah pengujian berhasil}}{\text{jumlah pengujian}} \times 100\%$$

$$\text{So } \frac{50}{50} \times 100\% = 100\%$$

The results of the NFC Tag implementation validation can be seen in Table 4.5 below.

Based on Table 4.5, all tested NFC Tags successfully passed the URL typing process, smartphone reading, and website verification. Each NFC Tag has a different URL address, resulting in information that matches the identity of each cable. Thus, the *smart cable labeling system* was successfully implemented with a 100% success rate.

Discussion of Research Results

The discussion aims to connect the research findings with the research problem formulation and objectives. Three main aspects discussed include system design, NFC tag

integration with the website, and system performance in improving cable identification efficiency.

System Design Discussion

smart cable labeling design successfully transforms cable identification patterns from conventional labels to digital ones. Conventional methods limit the information available on labels due to their small size. In the proposed system, physical labels serve only as a mounting medium for NFC tags, while complete information is displayed on the website.

This design meets the needs of the DVOR/ILS Laboratory, as the cables in the navigation system have functions and connection paths that require precise identification. With digital identification, users no longer need to manually search for cable information; they can simply scan to obtain more complete cable data.

Discussion of NFC Tag Integration with Website

NFC tag integration with the website is a key part of the system. The NFC tag stores a URL that leads to a cable detail page. When the tag is scanned, *the smartphone* opens the website and displays the cable information. This integration pattern makes the identification process more flexible because information can be updated on the website without having to replace the NFC tag as long as the URL remains the same.

Using a website also provides a broader range of information. Cable information includes not only cable codes but also functions, inputs, outputs, and technical specifications. This supports student learning, practical work, *maintenance*, and *troubleshooting* in the laboratory.

System Performance Discussion

System performance was assessed through reading distance and response time tests. Distance test results showed that NFC tags were most stable when read at distances of 0.5 cm to 3.0 cm. This result is consistent with the character of NFC as a short-range communication technology. Response time test results showed that the system required an average of 0.76 seconds to display cable information. This time is considered fast for laboratory identification purposes. With this response time, users can obtain cable information without opening manual documents or tracing cable paths directly.

Table 3. Comparison of Conventional Labels and *Smart Cable Labeling*

No.	Aspect	Conventional Labels	NFC-based <i>smart cable labeling</i>
1.	Information capacity	Limited to code or shorthand.	Can display complete data via the website.
2.	How to access information	Read directly on the physical label.	Accessed by scanning the NFC Tag using <i>a smartphone</i> .
3.	Identification speed	Depends on the user's ability to read and trace cables.	Information appears automatically after the tapping process.
4.	Risk of error	Higher if the label is damaged, faded, or the information is incomplete.	Lower because the information is arranged in detailed pages.
5.	Data update	Need to replace physical label.	Can be updated on the website as long as the URL remains in use.

6.	Suitability for Help with basic	Assists with identification, learning cable functions, and troubleshooting.
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The table shows that NFC-based *smart cable labeling* offers advantages in information capacity, ease of access, and flexibility in data updates. This system does not replace the technical functions of DVOR/ILS equipment, but it does support the cable identification process, making it faster, more organized, and more documented.

Advantages and Limitations of the System

The designed system has several advantages. First, the system makes it easier for users to quickly obtain cable information via *smartphone*. Second, the system displays cable data more completely than ordinary physical labels. Third, the system can assist in practical activities, *maintenance*, and *troubleshooting* because cable input and output information are available on one page. Fourth, information updates can be done through website files without replacing the entire physical label. The system also has limitations. First, users need a *smartphone* that has NFC features. Second, website access requires an internet connection. Third, the system only functions for identification and presentation of information, not for controlling DVOR/ILS equipment. Fourth, the *smart cable labeling system* has limitations in terms of security because the website still uses the GitHub Pages public service so it requires an internet connection to access information. In addition, NFC Tags do not use additional protection so that data on the tag has the potential to be changed if rewritten using a suitable device.

CONCLUSION

Based on the results of research and discussion regarding the design of smart cable labeling based on Near field communication in the DVOR/ILS Laboratory of the Medan Aviation Polytechnic, the following conclusions were obtained: (1) An NFC-based smart cable labeling system has been successfully designed and implemented using an NFC-enabled smartphone, an NTAG213 NFC Tag, an NFC Tools application, an HTML and CSS-based website, and GitHub Pages as a website publication medium. This system can be used as a digital cable identification medium, so that cable information can be presented in a more practical, structured, and easily accessible manner. (2) The integration between the NFC Tag and the website was successfully achieved by entering the URL of the cable information page into the NFC Tag using the NFC Tools application. After the NFC Tag is attached to the cable and scanned using a smartphone, the system can open a website page containing cable information, such as the cable name, function, input, output, and technical specifications. Thus, the NFC Tag can function as a link between the cable's physical label and digital information. (3) The test results show that the system has good performance for the cable identification process. NFC Tags can be read at a distance of 0.5 cm to 4.0 cm, with the most stable reading in the range of 0.5 cm to 3.0 cm and an average successful reading distance of 2.25 cm. The response time test produces an average of 0.76 seconds, so that the cable information page can be displayed quickly after the scanning process is carried out. This system is able to help the cable identification process more efficiently and reduce the need for manual cable tracing in practical activities, maintenance, and troubleshooting.

Suggestion

Based on the results of the research that has been conducted, several suggestions for further system development are as follows: (1) The NFC-based smart cable labeling system can be developed by adding an easier cable data update feature, so that cable information on the website can be updated quickly if there are changes in the function, input, output, or technical specifications of the cable. (2) The cable information website's interface can be developed to be more interactive and user-friendly, for example by adding a cable search feature, cable categories, or a more structured cable list display. These improvements can help users find cable information more quickly. (3) When installing NFC tags on cables, ensure they are easily

accessible and protected from friction or physical damage. This ensures the NFC tags remain easily scannable and can be used for extended periods of time during lab work, maintenance, and troubleshooting. (4) Further research could develop a smart cable labeling system by implementing a local laboratory server, an administrator authentication system, and a data backup mechanism to enhance system security and reliability. Furthermore, further development could include the addition of an integrated database and cable data management features to enable broader use in operational environments.

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