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GOES HDR
Latitude/Longitude/Transmitter Identification Implementation Study

V0.4

11/27/2023

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For

National Oceanic and Atmospheric Administration

National Environmental Satellite, Data, and Information Service

NOAA/NESDIS

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1 Introduction

The purpose of this document is to investigate implementation questions regarding the creation of a new geographical position-indicating message, known as a Lat/Lon/TxID message, intended for use on the National Oceanic and Atmospheric Administration (NOAA) Geostationary Operational Environmental Satellite (GOES) Data Collection System (DCS). The DCS service relays environmental monitoring data and telemetry from approximately 31,000 Data Collection Platforms (DCPs) in the western hemisphere.

Each DCP is an environmental monitoring platform principally owned and operated by US federal agencies. Some DCPs are owned by non-US federal agencies that have been granted standing by NOAA to use the DCS system. Each DCP is a standalone device that monitors the environment and reports scientific data, as well as DCP device telemetry using low data rate message communications. The device has an intelligent data processing capability and is usually battery powered. Solar panels are most often used to recharge the DCP batteries. A Global Positioning System (GPS) receiver is installed in each DCP and provides accurate position and timing information to the DCP. The GPS timing information is currently used to execute DCP message transmissions.

The messages transmitted by a DCP utilize either a 300 bits-per-second (bps) or 1200 bps data rate. There are two message types currently implemented for DCP transmissions, self-timed and random. Self-timed messages are scheduled to occur at a regular interval, often a one-hour interval, and are usually between 5 and 15 seconds in duration. The random message type is an event triggered transmission and can occur at any time. The random transmission messages have a much shorter duration of 3 seconds or less for a data rate of 300 bps.

Although not required, it is typical for each DCP to use the self-timed message type as its primary means of transmitting information, while relying on random messages for secondary transmissions that are event driven. According to the surveys conducted for the 2021 NOAA Random Channel User's Guide (NOAA 2021), fewer than 100 DCPs rely only on random message types.

The 31,000 NOAA DCPs are assigned message transmission frequency channels in a 330 kilo-Hertz (kHz) bandwidth between 401.70 and 402.03 Mega-Hertz (MHz). Specific channels are used for self-timed messages and they are different from the channels used for random messages.

The DCP self-timed message transmission windows are exclusive use time-slots assigned on a particular frequency channel. No other DCP may use that channel and time-slot for its self-timed message transmissions. This ensures a high probability of successfully receiving each individual self-timed message.

Random messages are unscheduled. This means it is possible for two DCPs, both assigned to the same channel, to transmit random messages at the same time, causing a collision and resulting in a failure of either DCP to communicate successfully. The DCS system was designed and is operated in a way that ensures these collisions are extremely rare, however, they do occur. The DCS system is nevertheless able to achieve better than a 95% success rate (NOAA 2021) in delivering these random messages by implementing a repeated message transmission scheme. Each DCP is programmed to send a sequence of several random messages, instead of one random message. A randomized interval is inserted between the messages to reduce the chance of additional collisions. The result is a system that can deliver random messages from any of the DCPs with a high probability of success.

Two important reasons for the successful performance of the DCS system that must be stressed here for this discussion are the ongoing careful management of the channel assignments for both self-timed and random channels that NOAA executes, and the ongoing adherence to the DCS specifications, best practices, and user guides, that DCS users and equipment vendors observe. It is essential for a distributed satellite communications system like the DCS to function successfully that these two important conditions be maintained.

There is a third message type that the DCS system is capable of handling but it has not been implemented yet. It is also not transmitted by DCPs, but rather received by them. This new message type is called the Two Way message and it may eventually have an important role to play in the transmission of the Lat/Lon/TxID message. The Two Way message type was described in the Random Channel User's Guide (NOAA 2021) this way:

> *"Once implemented, this message type will create a two-way link with remote DCPs for management purposes. The capability of having DCPs not only transmit messages with environmental data, but also receive command messages, is intended to enhance the transmissions of self-timed and random reporting message types by permitting the control of DCPs via remote communications. It will be possible, for instance, to remotely re-program, re-configure or shut-off a DCP that is transmitting incorrectly and interfering with other DCPs."*

With the above understanding of the DCS system in mind, the subject of this study can now be discussed. To properly manage the DCS with tens of thousands of deployed DCPs, it is imperative that NOAA maintain accurate platform data information including location, transmitter type and manufacturer, and operational assignment information. The DCS Administration and Data Distribution System (DADDS) and database are the primary tools employed to allow entry, storage and maintenance of this critical data.

While some of this information is assigned and entered by NOAA, users of the DCS are required to enter and maintain the site-specific information. However, often this data is not entered into DADDS. Recently, NOAA has expressed a desire to facilitate the site-specific data entry process. Specifically, NOAA wants to automate the entry of DCP location and radio information in the DADDS database by requiring DCPs to report their location automatically.

To achieve this automatic reporting a solution that leverages the existing DCP hardware to send an occasional position and transmitter identification message was conceived. The onboard GPS receiver already provides the desired location information to the DCP, and the DCS radios can be easily programmed to report their manufacturer, model, and serial number. In addition, a draft Lat/Lon/TxID message protocol has been developed to support this solution (NOAA 2023). By implementing the solution with only firmware changes to the DCPs that include the use of this new message protocol, it is believed that

NOAA's need for better DCP identification information can be achieved with minimal impact to the DCS system, the users, and manufacturers. Moreover, it is anticipated that NOAA and the entire DCS community will benefit greatly from the implementation of the Lat/Lon/TxID.

The current expectation is that these new position messages will be sent on one or more DCS channels in a manner similar to the way random messages are transmitted now. Utilizing the random reporting methodology described above will reduce the amount of coordination required. Although all DCPs will be required to transmit Lat/Lon/TxID messages, the messages will not be transmitted often and it is therefore expected that the additional traffic will not impact the performance of the DCS system. This issue is discussed further, below in this study.

While this system wide change is a NOAA requirement, it is recognized that the change brings a significant potential benefit to the user community. Many modern enterprises have initiated fixed asset management strategies to help increase their knowledge of the status and actual location of the equipment and infrastructure they own. This can bring many benefits to the enterprise, including improved operations, maintenance, inventory control, audit support, and loss prevention. It is hoped that many DCS users will embrace the addition of the new Lat/Lon/TxID message as an opportunity to improve their DCP asset management strategy.

The document presented below addresses the implementation questions surrounding this new position message that have been identified in various working group meetings and during the development of the Lat/Lon/TxID message protocol. The questions are presented as individual topics. For each implementation question, there is a discussion of the related issues, then solutions are discussed and considered, and finally recommendations for addressing the question are presented. After all the implementation questions are presented, the document concludes with a summary of the recommendations. References and an Appendix detailing the statistical backup for some of the recommendations are presented last.

2 Implementation Questions

To implement the DCS Lat/Lon/TxID message several questions regarding different implementation issues must be answered. Below, each question is discussed separately and presented with potential solutions and recommendations.

2.1 When to send a Lat/Lon/TxID message?

2.1.1 Discussion

It is anticipated that the Lat/Lon/TxID message will be transmitted at some predetermined time or event and/or on a regular interval by each DCP. How often the message is sent is one question that needs to be answered. The principal reason for implementing the Lat/Lon/TxID message is to validate the DCP's position and provide associated deployment information of DCPs. To this end, an on-deployment-only update or extremely-infrequent-interval (e.g. annually) transmissions may be sufficient. However, it is recognized, that the implementation of the Lat/Lon/TxID message creates the opportunity for DCS users to implement a fixed asset management strategy and this may require more frequent transmissions. Unless focused on loss prevention, most fixed asset management strategies use infrequent update rates ranging from quarterly to annual or even biennial.

2.1.1.1 Lat/Lon/TxID Scheduling

When exactly to send the Lat/Lon/TxID message is another aspect of this implementation question. This second issue is more complicated than it appears because there may be system performance impacts if the transmission times are not assigned properly. Consider the difficulty that might arise if all the DCPs from a large DCS system user were programmed to send their Lat/Lon/TxID message once a year, at midnight on New Years Day. While the interval is acceptable, the concurrent transmissions may cause a significant increase in traffic on the DCS system and result in unnecessary message collisions. Although less attractive for inventory verification purposes, maintaining a distributed schedule of reporting Lat/Lon/TxID messages from DCPs should be the goal for reducing message collisions. One potential solution for this issue is to refer to a DCP's first initialization date and time as the reference point for generating the Lat/Lon/TxID message. It is unlikely that large quantities of DCPs will be brought online and initialized in the same minute or same hour on the same day, so collisions would be reduced significantly.

2.1.1.2 Deployment and Power Up Concerns

Another aspect of this implementation question needs to address whether a transmission is sent during the actual DCP deployment, initialization, and/or resetting process. It is desirable to have a DCP send a Lat/Lon/TxID message soon after it is installed, to ensure its location is properly recorded in DADDS. While it may seem like an attractive solution to have a DCP transmit a Lat/Lon/TxID message on power up, if a DCP is power cycled multiple times during an installation it will send multiple unnecessary Lat/Lon/TxID message. Similarly, if a DCP's solar powered battery system is malfunctioning and shuts down each night, only to restart after sunrise, then the number of Lat/Lon/TxID transmissions would increase unnecessarily. To address this, it may be appropriate to maintain a non-volatile memory entry with the last Lat/Lon/TxID transmission date, time, and location. A comparison check with the current date, time, and location would ensure premature messages are not sent, simply because of a reset condition.

2.1.1.3 Lat/Lon/TxID Message Priority

One final aspect of this question that should be addressed is that Lat/Lon/TxID messages are not as mission critical as the data messages sent by the DCPs. In general, these location messages are lower priority than either self-timed messages or random messages. Therefore, they should be handled as lower priority messages in any DCP transmitter message queue. In addition, if the battery energy in a DCP has become depleted and there is the possibility that a Lat/Lon/TxID message will consume the remaining available battery energy, precluding additional data transmissions, then the Lat/Lon/TxID transmission should be postponed. Once, the battery has been recharged the Lat/Lon/TxID message can be sent.

After reviewing the complexity of this question and having considered when different DCPs might transmit their Lat/Lon/TxID message, a further refinement of the interval assignment may be appropriate. Just as DCP random messages do, it may be appropriate to incorporate a randomization adjustment on the time interval used for transmission. With short duration messages, like the Lat/Lon/TxID message, even a small randomization adjustment of several minutes would help subjugate any operational phenomenon that might tend to cause collisions by having DCPs send their Lat/Lon/TxID messages at the same time.

2.1.2 Recommendations

To address the implementation questions regarding when the Lat/Lon/TxID message should be sent, the following recommendations are provided for consideration:

1) Transmit an on-deployment position message followed by a standardized semi-annual reporting interval. As discussed in the Appendix, this interval will not create a traffic impact for the DCS system assuming the Lat/Lon/TxID message transmissions are distributed over an appropriate number of channels. The benefit of using such an interval is in supporting as many fixed asset management strategies as possible, while accomplishing the primary NOAA mission. As is done with random messages, include a 5-minute uniform randomly distributed transmission start window, in this case centered on the end of the semi-annual interval.

2) Establish each DCP's initialization date and time as its reference for reporting intervals. This will ensure large numbers of DCPs do not transmit their Lat/Lon/TxID messages at the same time.

3) Maintain the date, time and location of the last Lat/Lon/TxID transmission in non-volatile DCP memory so that unnecessary transmissions do not occur.

4) Assign Lat/Lon/TxID messages to be low priority for DCP message transmission sequencing and queueing.

5) Set a programmable battery voltage threshold below which Lat/Lon/TxID message transmissions will be postponed, to ensure mission critical data has priority in a low-power condition.

2.2 How many repeated Lat/Lon/TxID messages to send?

2.2.1 Discussion

The Lat/Lon/TxID messages will be sent on a channel that is shared with other DCPs sending Lat/Lon/TxID messages and perhaps even random messages. This means there is a chance that a single Lat/Lon/TxID message will be sent at the same time another DCP message is being sent. The NOAA random message user's guide (NOAA 2021) discusses the probability of successfully delivering a single random message and the results can be considered for the transmission of a single Lat/Lon/TxID message. If a typical channel experiences enough message traffic so that it is greater than about 2.5% loaded, then the probability of a single Lat/Lon/TxID message being delivered successfully falls below 95%. Most of the current channels used for random messages are not loaded above 2.5% but this may change in the future. Adding the Lat/Lon/TxID messages from several tens of thousands of DCPs will impact this loading slightly as well.

One alternative solution to sending only a single message is to send a sequence of repeated Lat/Lon/TxID messages, as is recommended for random messages by the NOAA random message user's guide (NOAA 2021). By sending 3 repeated copies of the message, spaced in time with appropriate randomized intervals, the probability of success is maximized while achieving the highest possible use (throughput) of the channel.

Assuming the additional copies do not significantly impact message traffic (this issue is addressed below in the channel assignment discussion) it seems appropriate to transmit additional repeated copies of the Lat/Lon/TxID message.

2.2.2 Recommendations

Maintain a minimum probability of success of 95% for the delivery of Lat/Lon/TxID messages, while efficiently using assigned DCS channels, by sending 3 copies of the message.

2.3 What repeated Lat/Lon/TxID message interval to use?

2.3.1 Discussion

If repeated copies of the Lat/Lon/TxID message are to be sent to improve the probability of successfully delivering the message then the interval between the transmissions of repeated copies must include two particular statistical features to be effective. First, the interval must be sufficiently long, compared to the message length, to create statistical independence between the message copies. This will significantly reduce the chance of back-to-back copies from different DCPs colliding with each other. Second, the interval must have a random component so that if collisions do occur during an initial Lat/Lon/TxID message transmission, they will be much less likely to occur during the transmission of copies (because the transmission time of the next copy has been randomized).

The draft Lat/Lon/TxID message length is similar to that of a maximum size random message (NOAA 2023), with a duration of nearly 3 seconds. It is therefore appropriate to apply the same recommendations for random message intervals, also to Lat/Lon/TxID messages. The simulation results in the random message user's guide (NOAA 2021), verify that a 5-minute interval with a, plus-or-minus, one-minute randomized extension will ensure the desired probability of success for repeated copies of a random message. Although a faster interval is possible, the non-time sensitive nature of the Lat/Lon/TxID message does not justify the use of a shorter interval.

2.3.2 Recommendations

If repeated copies of the Lat/Lon/TxID message are to be sent, then to ensure the desired probability of successfully delivering the message, implement a 5-minute interval with a uniformly distributed, plus-or-minus one minute extension between the copies.

2.4 What channel(s) to use for sending Lat/Lon/TxID Messages?

2.4.1 Discussion

The Lat/Lon/TxID message will be transmitted from each DCP on one of the existing DCS channels. The assigned self-timed channels are inappropriate for sending the new uncoordinated Lat/Lon/TxID messages because they could interfere with the scheduled messages. One option would be to share existing assigned random channels requiring them to support random messages and Lat/Lon/TxID messages. Another option and the most likely candidate given that implementation of the Lat/Lon/TxID will roughly coincide with the culmination of the CS2 transition is to only utilize new CS2 channels for use as Lat/Lon/TxID channels.

2.4.1.1 Loading Analysis

The additional traffic on the DCS system from the anticipated Lat/Lon/TxID messages will not contribute significant loading if the messages are not sent frequently. If for instance, a semi-annual reporting schedule with three message copies for each platform is assumed, the current 31,000 DCPs will generate 77.5 hours of actual 3-second long Lat/Lon/TxID message traffic every 6 months; i.e. 3.23 days total transmission time[1]. If only sent on a single channel, this would still only represent a total channel loading increase of approximately 1.77%[2].

If random channels are used to share the traffic, their current level of traffic should be considered. There are currently 21 channels assigned for random message transmissions and the current assignments are distributed across the 21 channels in a relatively balanced manner. The loading on each of these channels is currently less than approximately 2.5%. This suggests the Lat/Lon/TxID message traffic could be added to one or more random channels without significantly impacting the performance of the

[1] If 31000 DCPs send three 3-second messages that is 31000 * 3 * 3 = 279,000 seconds or 4,650 minutes, or 77.5 hours or 3.23 days of transmission time (message traffic).

[2] The semi-annual 3.23 days of traffic would occur twice a year and represents an increase of 3.23 days of traffic * 2 / (365 days per year) =1.77% channel loading each year.

channels. If the Lat/Lon/TxID message traffic were evenly distributed across the 21 random channels, this would represent an addition of approximately 221 minutes of actual message traffic to each channel, spread out over 6 months' time[3]. Assuming all the messages were delivered this would increase each channel's throughput by 0.08%[4]. The NOAA random message user's guide discusses how many DCPs can be assigned to a channel when repeated copies are sent. As discussed in the Appendix of this document, by extrapolating the results in the user's guide it is possible to show that *for semi-annual reporting intervals,* a single DCS channel can support approximately 400,000 DCPs sending random messages with 3 repeated message copies, maintaining a 95% probability of success. At first glance, this may seem like an extraordinary number of DCPs, but consider that the total traffic amounts to 400,000, 3 second transmissions in 6 months, plus the repeated copies. For the 3 repeated copies, this is equivalent to a total traffic loading profile of just 42 days of traffic during a - 6 month window, assuming there is no overlapping collisions, which of course there are, thus reducing the loading by the overlaps[5]. The throughput, however, remains low as expected with this type of communication scheme. At a 95% probability of success, the channel usage during a semi-annual 6-month period is only 7.2%[6]. Again, assuming the Lat/Lon/TxID message is similar in nature to a random message, this result will apply to the Lat/Lon/TxID message as well.

The above analysis clearly suggests that it is possible to utilize the existing random channels for Lat/Lon/TxID messages with little overall impact to the DCS from a loading perspective. However, there are other factors that should be considered.

2.4.1.2 Reasons for Not Using Existing Random Channels

One simple reason not to utilize existing random channels for Lat/Lon/TxID messages is that not all DCPs utilize random messaging. While this certainly wouldn't preclude a DCP from being assigned an existing random channel for Lat/Lon/TxID messages, it may be clearer and more straightforward for such users to utilize a dedicated "identify" channel.

Even for those users who do use random reporting, there may also be some who for operational reasons, would prefer to maintain separate random channel and Lat/Lon/TxID channels. NOAA could obviously handle such situations on a case-by-case basis. On the other hand, having a common identify channel assignment methodology would certainly facilitate management and avoid confusion.

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[3] The 31,000 DCPs would generate 4,650 minutes of Lat/Lon/TXID message traffic every 6 months[1]. Divided over 21 channels this represents 4,650 / 21 = 221 minutes of traffic per channel every 6 months.

[4] The 221 minutes of additional channel traffic represents 3.69 hours or 0.15 days of traffic every 6 months. Computed annually this represents an increase of 0.15 days of traffic * 2 / (365 days per year) = 0.084% channel loading.

[5] In a 6-month window 400,000 DCPs would send 3 copies of a 3 second message or 1,200,000 3 second messages. This is 1,200,000 * 3 = 3,600,000 seconds of traffic or 60,000 minutes of traffic or 1,000 hours of traffic or 41.667 days of traffic.

[6] The channel usage is 400,000 messages x 3 seconds x 95% / (60 seconds per minute) / (60 minutes / hour) / (24 hours / day) / (365 / 2 days per 6 months) = 7.2%.

One other consideration to add to this reasoning is that the DADDS channel database already includes channel utilization descriptions. As such, it may prove useful for the DCS community at large to have the identify channels clearly designated in DADDS.

Finally, it has also been suggested that it may actually be more appropriate to have a predefined Lat/Lon/TxID channel, or set of channels, specified by NOAA and require that the DCP vendors program these channels into each DCP to avoid assignment mistakes and confusion. To support any required future and/or unexpected changes, users would only be allowed to alter the predefined identify channel(s) with a special password obtained from the transmitter manufacturer.

2.4.1.3 Single Channel versus Multiple Channels

Radio Frequency Interference (RFI) is nothing new to the DCS, but recent issues have made it a more significant concern, and one that must be considered for a Lat/Lon/TxID implementation. Specifically, how can the implementation proactively address potential RFI; as opposed to reactively trying to mitigate RFI issues for Lat/Lon/TxID.

The proactive approach boils down to a simple consideration: single channel implementation versus a multiple channel implementation. Obviously, utilizing a single channel for all Lat/Lon/TxID messages means that a single continuous RFI signal could disrupt the entire identify system. However, would use of multiple channels waste resources?

This question also ties back to the use of existing random channels. If existing random channels are utilized, and DCPs simply utilize their assigned random channel for identify messages, and this would naturally spread distinct DCPs across multiple channels. On the other hand, this also means that each DCP only has a single channel to report Lat/Lon/TxID messages.

This leads to a corollary question: should these Lat/Lon/TxID messages be sent on multiple channels? In other words, in addition to sending the repeat messages with random timing, the repeated messages could also be sent on different channels. This approach would proactively mitigate RFI on a single dedicated identify channel.

Use of multiple channels for all DCPs clearly ties into the utilization of only CS2 channels for the Lat/Lon/TxID since of the over 200 possible 300 bps interstitial CS2 channels, less than half a dozen have currently been assigned.

2.4.1.4 Summary

As a summary and to further consider the channel assignment options available for the new Lat/Lon/TxID message, a comparison table is provided below. In Table 1, three identified options are presented along with the advantages and disadvantages each option offers.

As is noted in Table 1, the first two options (utilizing CS2 channels or extending random channel functionality) can be implemented in ways that minimize the risk of RFI. By using different channels to send the recommended three copies of the Lat/Lon/TxID message, the risk that RFI affecting one channel will prevent the delivery of the message is mitigated to a great extent.

If there is significant concern for DCS users, who operate Direct-Readout Ground Station (DRGS) equipment, not having sufficient receiver channels available to implement three additional channels for receiving all the copies of the Lat/Lon/TxID message, then a hybrid option may be appropriate to consider. If the assigned DCP random channel is selected as one of the Lat/Lon/TxID channels, two additional CS2 channels could be used for EMI mitigation. This would allow DCS users to receive the Lat/Lon/TxID messages from their DCPs while simultaneously ensuring the highest probability of success, with EMI mitigation at the NOAA receiver sites.

Table 1: Channel Assignment Options for Lat/Lon/TxID Messages

Channel Assignment Option	Advantages	Disadvantages
Assign one or more CS2 channels	• Utilize currently unused DCS channels. • Easy to manage. • No confusion with mixed message traffic. • RFI mitigation is easy to do by using separate channels for the Lat/Lon/TxID message copies.	• Reduces number of available CS2 channels. • DCP must be programmed for transmissions on one or more additional channels. • DRGS users may need additional receiver channels.
Assign one or more random channels	• Easy to manage. • No confusion with mixed message traffic. • EMI mitigation is easy to do by using separate channels for the Lat/Lon/TxID message copies.	• Reduces number of available random channels. • Existing random channel assignees must vacate the designated channels. • DCP must be programmed for transmissions on one or more additional channels. • DRGS users may need additional receiver channels.
Share existing random channels	• RFI mitigation is easy to do by using separate channels for the Lat/Lon/TxID message copies. • Fewer additional channels needed for DCP programming. • DCS users maintain current channel assignments.	• More difficult to manage. • Potential for confusion with mixed traffic messages on the same channel. • Reduced EMI immunity since only one channel is used to send all copies of the Lat/Lon/TxID message.

2.4.2 Recommendations

For each DCP, create a three-random-channel configuration for Lat/Lon/TxID message transmissions consisting of the assigned random channel and two new dedicated Lat/Lon/TxID message CS2 channels assigned to all DCPs.

For users who do not utilize random reporting, assign one of the existing random channels and instruct users to program this channel into the DCP, but do not set up a mechanism to trigger random reports (unless they wish to start using random reporting). Since the random report methodology is event driven, by simply not implementing a trigger event will result in this channel only being one of the three identify channels utilized by this platform.

To encourage compliance, default DCP configurations should include the Lat/Lon/TxID channel information under special password protection so it cannot be changed accidentally.

2.5 How are DCP power up and initialization conditions addressed?

2.5.1 Discussion

The DCP power up and initialization process is sufficiently complicated that it requires additional discussion beyond its brief mention above in implementation question one (Section 2.1). As with other DCP transmission configuration parameters, the required Lat/Lon/TxID message parameters should be stored in non-volatile memory. After power up or initialization, the DCP should wait until it has GPS lock and sufficiently accurate time and position information when deciding if it should send a Lat/Lon/TxID message.

As recommended above, the DCP should maintain knowledge of when and from where it sent its previous Lat/Lon/TxID message and use that information to determine during power-up or initialization if a new position message should be sent.

In addition, the decision process should also consider the frequency channel assignment so the last channel used to send a Lat/Lon/TxID message should also be saved. This will assist maintainers who are changing channel assignments or reusing a previously used DCP on a different channel. If the channel assignment is different than the last time a Lat/Lon/TxID message was sent, it may be appropriate to send a new message on power up or initialization.

Another aspect that should impact the decision to transmit on power up or initialization is movement. If the DCP notes physical movement outside some margin of geofenced circular area, referenced to the previous location transmitted, then a new Lat/Lon/TxID message is likely warranted on power-up or initialization.

The three above decisions (time since last message, frequency channel of last message, and location of last message) should be implemented in a logical OR function where if any one of the three conditions is met, then a transmission is warranted. As discussed above, any decision to send a Lat/Lon/TxID message should also be evaluated against the available battery power.

2.5.2 Recommendations

To support power up and initialization processes a DCP should perform a Boolean decision to determine if a new Lat/Lon/TxID message should be sent. Included in the decision should be when the last message was sent, where the last message was sent from, and what key parameters have changed. In any event, if battery power is depleted, a new Lat/Lon/TxID message should be postponed until the battery is recharged.

Figure 1 below shows a suggested decision flowchart that encompasses these powerup or restart decision elements. As covered in the Notes section, this flowchart assumes that no transmissions are made until the initial GPS sync to set the transmitter's clock, which will also provide position, and assumes that the transmission sequence already handles low power conditions. This flowchart also captures recommendations from earlier sections, and further adds the following retransmit time/date and position limits:

Days Since Last Identify Message Limit = 180

GPS Sync with Position Change Limit = 100 meter

Restart Time Limit = 48 hours

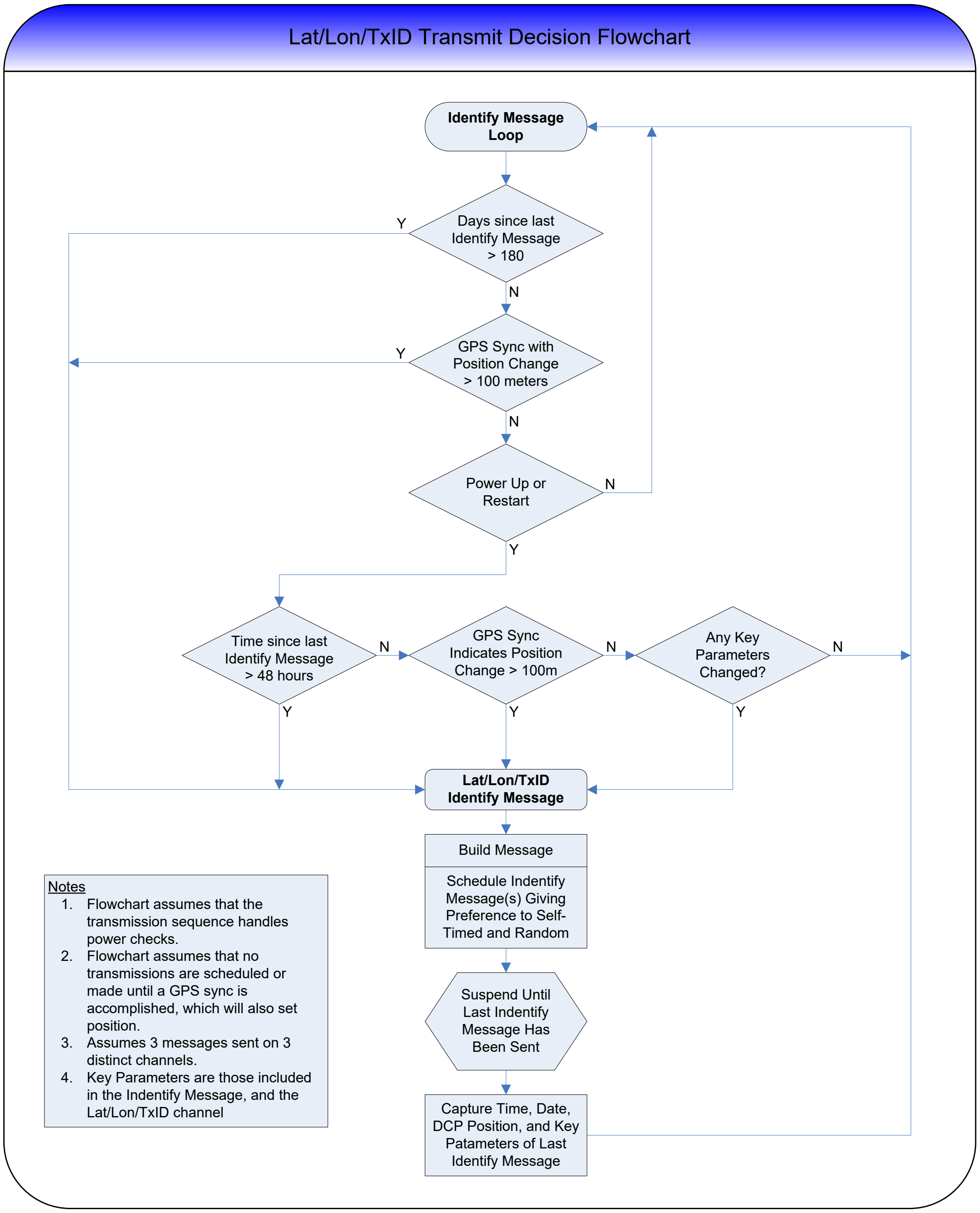

Figure 1: Lat/Lon/TxID Transmit Decision Flowchart

2.6 What will be the impact of the new Two Way system?

2.6.1 Discussion

When implemented, the Two Way message process will allow DCPs to receive commands and make adjustments and corrections that will improve DCP operation but also potentially DCS operation. There are several likely improvements that have already been identified that will directly or indirectly impact the Lat/Lon/TxID message and its operation. These improvements are discussed here to ensure that DCP manufacturers and DCS users are aware of them now and will support them.

One of the biggest impacts will be the ability to reduce message traffic and recover channel loading capacity. In the case of the Lat/Lon/TxID message, once a Two Way message is possible, it will not be necessary to send a repeated copy of the Lat/Lon/TxID message. The DCP need only wait for an acknowledgement to be sent to it via the Two Way link. If an acknowledgement is not received, then the DCP can proceed with a Lat/Lon/TxID message retransmission. Since latencies for such acknowledgements have not yet been defined, it may be necessary to expand the fixed part of the Lat/Lon/TxID message repeat interval beyond 5 minutes to allow time for the Two Way acknowledgement to be sent.

The Two Way message will also allow NOAA, or an approved DCS user, to manually command an individual DCP to send a Lat/Lon/TxID message. This would supersede the scheduled, e.g., semi-annually, transmission and send the message immediately. This capability has utility for maintenance activities and support with lost (adrift), misplaced, or even stolen DCPs.

A third benefit from the Two Way message that will impact all DCP configuration parameters is the ability to update them and in the case of message transmissions, when necessary, to disable them. The parameters of the Lat/Lon/TxID DCP configuration should be remotely configurable and it should be possible to remotely disable and reenable the transmission of Lat/Lon/TxID messages.

2.6.2 Recommendations

The DCP manufacturers should implement Lat/Lon/TxID messaging in a way that can benefit from Two Way messaging, as discussed above.

3 Lat/Lon/TXID Traffic Impact on DCS

The proposed new Lat/Lon/TxID message traffic will be added to the existing DCS message traffic. If it is assumed that the Lat/Lon/TxID messages will be sent with 3 redundant copies, and further assumed that one each of the copies will be distributed on 1 current random channel and two new CS2 channels, then the analysis of the impact of the new traffic can be conducted in two parts. The first part of the analysis is to consider the impact of the new traffic on a new CS2 channel, and the second part of the analysis is to consider the impact of the new traffic on an existing random channel.

The new traffic will consist of Lat/Lon/TxID messages that are transmitted at a proposed regular interval of once every 6 months. In addition, the traffic will include Lat/Lon/TxID messages when a DCP is first deployed or it is activated (a smart designation that does not include merely power-cycling an unchanged DCP). There are currently approximately 31,000 DCP assignments in the DCS system. If the 31,000 platforms each transmit a Lat/Lon/TxID message once every 6 months, using 3 message copies, that will represent a total traffic increase on the DCS system of 93,000 messages in 6 months, or 21.2 messages per hour, assuming they are evenly distributed[7].

In addition, if we assume that the DCS system experiences 8 new deployments or activations[8] per day, then there will be 24 additional Lat/Lon/TxID messages added to the system each day. This additional traffic brings the total traffic increase up to 97,380 messages in 6 months, or 22.2 messages per hour[9]. The estimate of 8 deployments or activations per day is a conservative estimate. Using previous deployment data from 2014 to 2019, it was determined that in that 6-year period there was an average of 4.2 deployments per day. This deployment data is shown below in Figure 2 along with an increased estimate of 5.1 deployments per day for 2023. The slight trend upward is the reason for using the higher number of 8 deployments per day in this analysis. It is important to note, an activation can occur when a new DCP is deployed, or an existing DCP has not transmitted any messages for at least two days.

We will assume the new traffic will be distributed across two satellites, reducing the hourly message rate to 11.1 messages per hour per satellite. Remembering that there are three copies of each Lat/Lon/TxID message in the traffic, one copy of each message will be carried on a new CS2 channel. Therefore, the traffic rate on each of the two new CS2 channels will be 11.1 / 3 = 3.71 messages per hour. Recalling that each Lat/Lon/TxID message is 3 seconds long, this channel loading will yield an individual channel

[7] There will be 31,000 * 3 = 93,000 messages sent every 6 months. Since there are (24 hours / day) * (365 / 2 days per 6 months) = 4,380 hours in 6 months, there will be 93,000 / 4,380 = 21.2 messages per hour.

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[9] With 24 additional messages per day, over six months this is an increase of 24 * 365 / 2 = 4380 messages, bringing the total to 93,000 + 4,380 = 97,380 messages per six months. With 4,380 hours in 6 months this is an increased message rate of 97,380 / 4,380 = 22.2 messages per hour.

probability of success of 99.4%[10] to carry a single Lat/Lon/TxID message on a new CS2 channel.

From 2019 DCS2-ARCA Database								
Month	2019	2018	2017	2016	2015	2014		
January	62	71	79	57	107	73		
February	74	85	107	100	81	100		
March	80	136	124	104	124	112		
April	113	82	150	113	136	118		
May	146	138	154	138	138	188		
June	107	139	158	137	155	150		
July	125	148	121	94	160	151		
August	126	143	140	178	122	190		
September	115	171	144	148	164	196		
October	137	204	148	142	156	226		
November	119	146	148	213	100	167		
December	49	81	85	132	113	95	Average	2023 Est.
Per Year	1253	1544	1558	1556	1556	1766	1538.8	1846.6
Per Month	104.4	128.7	129.8	129.7	129.7	147.2	128.2	153.9
Per Day	3.4	4.2	4.3	4.3	4.3	4.8	4.2	5.1

Figure 2: DCP Deployment Data 2014-2019

The existing random channels already have traffic on them so this must be considered before we add the new Lat/Lon/TxID messages to the random channels. In 2020, 20 random channels were studied, and their traffic analyzed, to help prepare the NOAA DCS Random Channel User's Guide. Assuming these 20 channels will be used to carry new Lat/Lon/TxID messages we can use the statistical analysis of the random channel traffic to baseline the initial conditions before we add the Lat/Lon/TxID traffic. The twenty channels carried an average of 34.46 messages per hour. The maximum rate on any channel was 108 messages per hour, and the minimum was 0.12 messages per hour. The standard deviation was 29.67 messages per hour. The average random channel experiences a probability of success for delivering a random message of 99.7%[11] assuming two copies were sent. If one copy of the new Lat/Lon/TxID traffic is carried on the random channels then we can assume we will distribute the traffic on the 20 channels evenly. This will distribute the 3.71 messages per hour onto the 20 random channels,

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[10] The probability of success of an individual message can be solved with the classic Poisson analysis for the Aloha protocol yielding a probability of success of $P_s = e^{-2\tau\lambda_t}$, where τ is the message duration and λ_t is the total message rate. In this case, $\tau = 3\ seconds\ or\ \frac{3}{3600}\ of\ an\ hour$ and $\lambda_t = 3.71\ messages\ per\ hour$.

[11] From equation A17 in the Random Channel User's Guide, the probability of success is $P_s' = 1 - \left(1 - e^{-2\tau\lambda_t'}\right)^r$ where τ is the message duration, λ_t' is the total message rate including random message copies, and r is the number of copies sent. In this case, $\tau = 3\ seconds\ or\ \frac{3}{3600}\ of\ an\ hour$, $\lambda_t' = 34.46\ messages\ per\ hour, and\ r = 2$

creating an increase in traffic on each random channel of 0.19 messages per hour. The new random channel average message rate will become 34.65 messages per hour. For the single Lat/Lon/TxID messages on the random channel, this will yield an individual channel probability of success of 94.4%[12]. The average random channel that is sending 3 copies in each random message will see a slight decrease in performance because the additional traffic. The new average random channel probability of success will remain 99.7%[13]. This essentially zero-impact of adding the Lat/Lon/TXID messages to a random channel is shown graphically in the histogram and pie chart in Figures 3 and 4.

To compute the overall probability of success of delivering a Lat/Lon/TxID message, we must combine the probabilities of success from the three channels. When we do, we find the probability of successfully delivering a Lat/Lon/TxID message with the three channel approach is 99.9998%[14].

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[12] In this case we use $P_s = e^{-2\tau\lambda_t}$, with $\tau = 3\ seconds\ or\ \frac{3}{3600}\ of\ an\ hour$ and $\lambda_t = 34.65\ messages\ per\ hour$.

[13] In this case we use $P_s' = 1 - \left(1 - e^{-2\tau\lambda_t'}\right)^r$, with $\tau = 3\ seconds\ or\ \frac{3}{3600}\ of\ an\ hour$, $\lambda_t' = 34.65\ messages\ per\ hour, and\ r = 2$

[14] With three channels sending LatLonTxID messages, there are 8 possible combinations of success and failure in sending the messages. Any combination with an individual channel success yields a successful outcome for delivering the message. Among the eight combinations, only 1 combination results in overall failure to deliver a Lat/Lon/TxID message (when all three channels fail to deliver their individual messages). If we compute this probability of failure, then the overall probability of success is found by subtracting the probability of failure we found, from 1. Thus the probability of success is 1 - (1-.944)*(1-.994)*(1-.994) = 99.9998%.

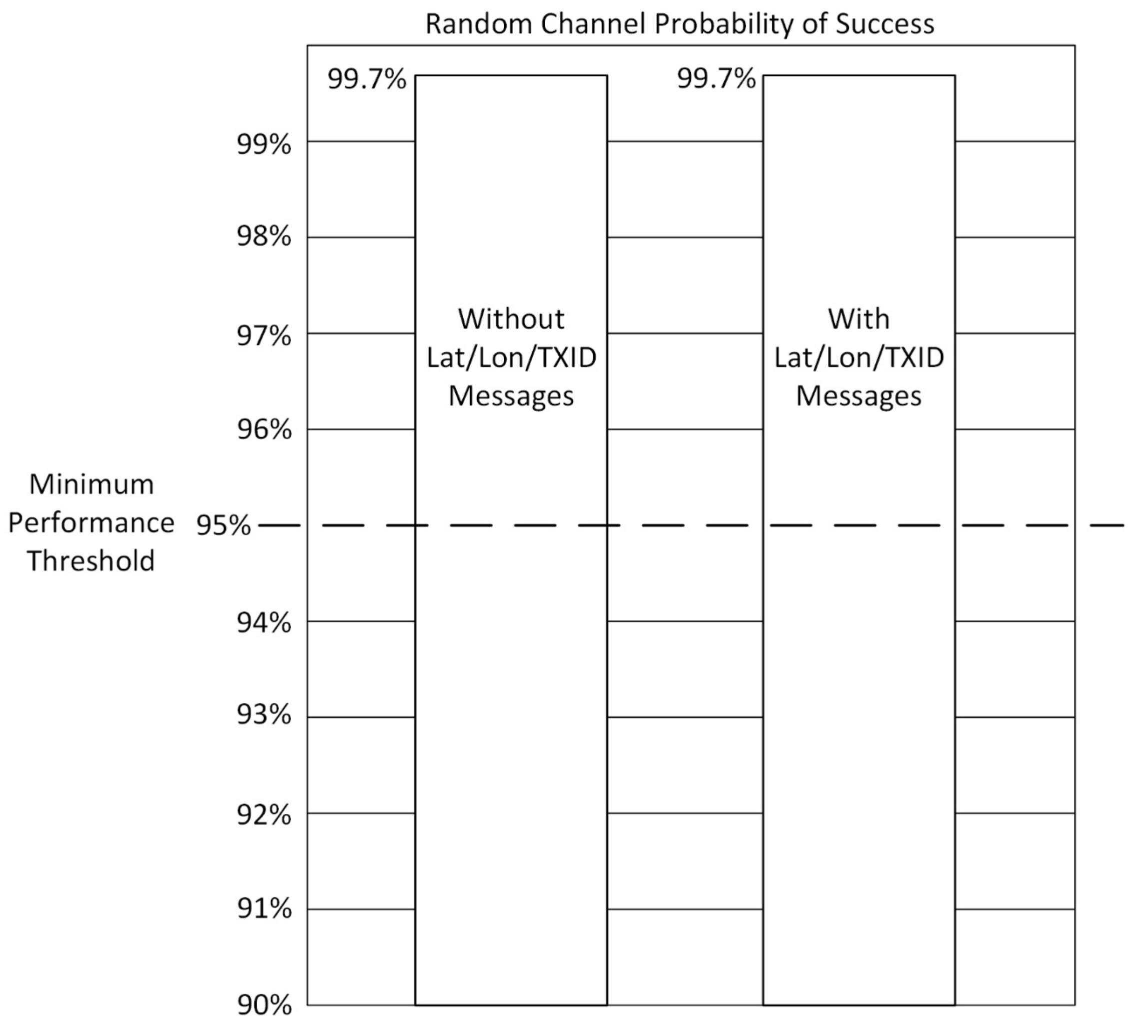

Figure 3: Random Channel Probability of Success with Lat/Lon/TxID (Bar)

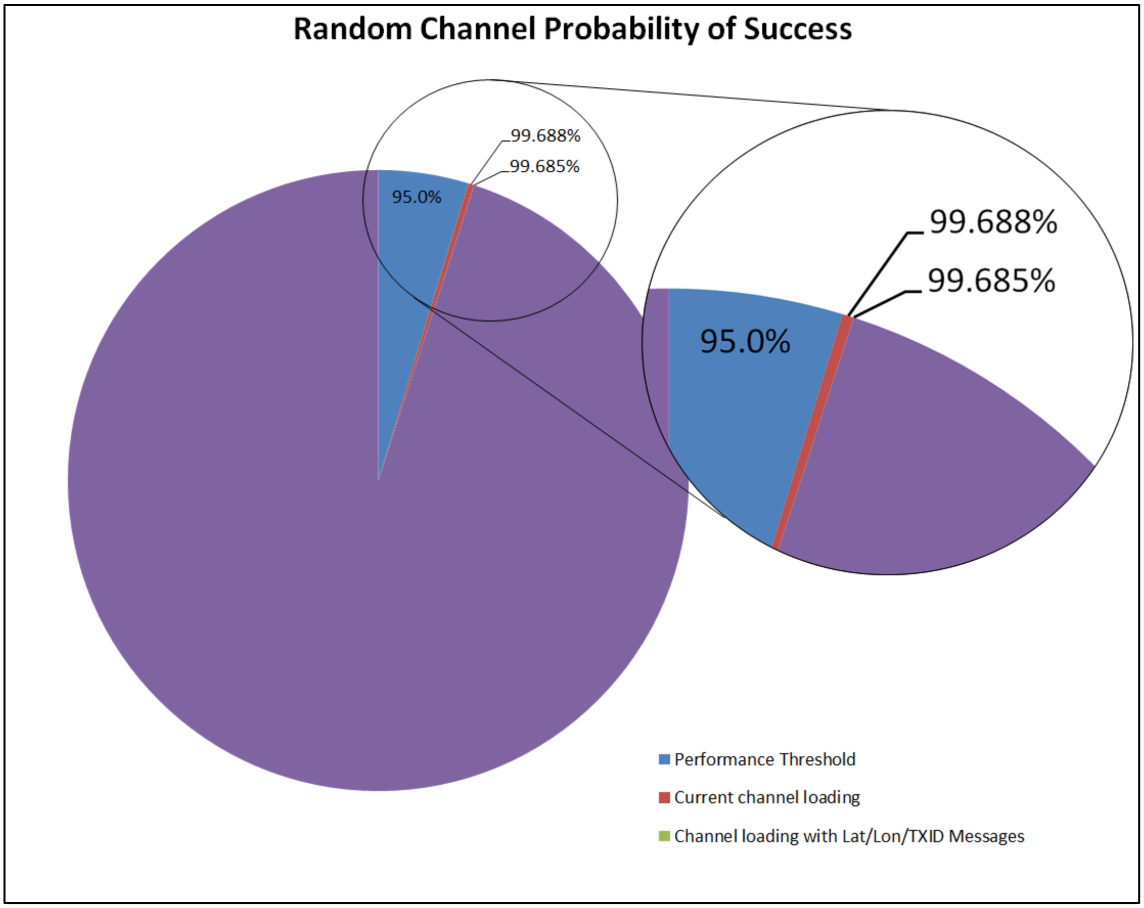

Figure 4: Random Channel Probability of Success with Lat/Lon/TxID (Pie)

4 Recommendations Summary

The recommendations from the above discussions are summarized below in Table 2. It was noted during the work on this document that the random message format does not identify which copy of a repeated message sequence a particular message is. While this has no impact on system performance, it does make traffic analysis much more difficult. For instance, it is extremely difficult, if not impossible to piece together a sequence of repeated messages and analyze actual traffic throughput. To avoid a similar challenge with Lat/Lon/TxID messages, it is recommended that the next version of the Lat/Lon/TxID message protocol specification include a field identifying how many message copies are sent, and which one in the sequence, each particular message is.

Table 2: Summary of Recommendations

Implementation Topic	Recommendation
2.1 When to send a Lat/Lon/TxID message?	Transmit on-deployment position messages and then semi-annually messages with a randomized time component, referenced from the deployment date and time, which is maintained in the DCP memory. Assign low transmission priority to Lat/Lon/TxID messages and delay their transmission if the battery voltage is below a programmable DCP performance-impacting threshold.
2.2 How many repeated Lat/Lon/TxID messages to send?	Maintain a minimum probability of success of 95% for the delivery of Lat/Lon/TxID messages, while efficiently using assigned DCS channels, by sending 3 copies of the message.
2.3 What repeated Lat/Lon/TxID message interval to use?	To ensure the desired probability of successfully delivering the message, implement a 5-minute interval with a uniformly distributed, plus-or-minus one minute extension between the copies.
2.4 What channel(s) to use for sending Lat/Lon/TxID messages?	For each DCP, create a three-channel configuration for Lat/Lon/TxID message transmissions consisting of the assigned random channel and two new dedicated Lat/Lon/TxID message CS2 channels assigned to all DCPs.

Implementation Topic	Recommendation
2.5 How are DCP power up and initialization conditions addressed?	To support power up and initialization processes a DCP should perform a Boolean decision to determine if a new Lat/Lon/TxID message should be sent. Included in the decision should be when the last message was sent, where the last message was sent from, and what key parameters have changed. In any event, if battery power is depleted, a new Lat/Lon/TxID message should be postponed until the battery is recharged.
2.6 What will be the impact of the new Two Way system?	The DCP manufacturers should implement Lat/Lon/TxID messaging in a way that can benefit from Two Way messaging, when enabled.

5 References

NOAA. (April 2023). Draft GOES HDR Latitude/Longitude/Transmitter Identification Lat/Lon/TxID Specification, Version 0.2. NOAA/NESDIS.

NOAA. (July 2021). User's Guide For The GOES DCS Random Reporting Channel. NOAA/NESDIS.

6 Appendix

From the performance analysis presented in the Random Channel User's Guide (NOAA 2021) we can predict the number of DCPs that can send Lat/Lon/TxID message traffic on a single channel. This is possible if the above recommendations are adopted and the proposed Lat/Lon/TxID protocol (NOAA 2023) is also adopted. Under those circumstances the message transmission profiles for Lat/Lon/TxID messages will be nearly identical to the limiting case for random messages analyzed in the User Guide (specifically 3 second maximum duration random messages).

The performance data in the User Guide presents an analysis of the maximum number of DCPs that can be supported on a DCS channel when sending 3 copies of a 3 second message, with a 95% probability of successfully delivering the message. The analysis is in Table A4 of the User Guide. The analysis is for a dedicated random channel so no other type of traffic is assumed to be sharing the channel (a realistic assumption for the DCS system). The number of DCPs that can be supported increases when the expected interval between independent random messages increases. This makes sense because of the reduction in the amount of original traffic on the channel for all DCPs as the interval increases. The longest interval analyzed in the User Guide was 1 week between random messages. The analysis showed that 15240 DCPs can be supported on a single channel if each message set (3 copies) from each DCP is sent one week apart.

For Lat/Lon/TxID messages we are interested in considering the recommended semi-annual interval, which is 26 times longer than the longest interval of 1 week, analyzed in the Random Channel User's Guide. The extrapolation for a semi-annual interval is presented here. We start with the transmission rate λ = 91.4 original messages per hour that can be supported assuming 3 message copies are sent and the desired probability of success is 95%, An individual DCP that sends a 3 second Lat/Lon/TxID message (3 copies) once every 6 months has a transmission rate of λ = 0.000228 messages per hour[15]. If the channel can support 91.4 messages per hour, then the number of DCPs that can send semi-annual Lat/Lon/TxID messages is 91.4 / 0.000228 = 400,332 DCPs. This analysis indicates that all of the Lat/Lon/TxID traffic can be supported on one or more channels.

[15] The original message rate is 1 message every 6 months or 1 message / (365 days / 2) / (24 hours / day) = 1 message / 4,380 hours = 0.000228 messages per hour.