NXDN™

Next Generation Digital LMR Technology.

NXDN™ OVERVIEW

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Section 1: What is NXDN™?

1.1 NXDN™: A brief overview

NXDN™ is a narrowband digital protocol, and is "6.25 kHz and 12.5 kHz FDMA technology". (It is generally accepted that 12.5 kHz channel spacing is narrowband as per the FCC mandate. More on this later in 1.2 The history of NXDN™).

NXDN™ is the result of a joint technical alliance between Icom Incorporated and JVC KENWOOD Corporation. At the beginning, the main goals of this collaboration were to provide a low complexity digital two-way radio protocol that satisfied the FCC narrowbanding mandate at the initially proposed deadline of 2005, be a future-proof protocol that would still be viable even when 12.5 kHz spectrum became full and to offer an alternative “de-facto” standard to the Land Mobile Radio (LMR) industry that allowed the development of digital radio products without the excessive premium some competing digital technologies were.

In the time that NXDN™ has been in existence, it is estimated that the number of radio terminals alone provided by the vendors with product has exceeded 1 million units worldwide, and is growing in the tens of thousands each month. NXDN™ has truly become a “de-facto” protocol as per one of the initial goals mentioned above.

1.2 The history of NXDN™

As mentioned above, NXDN™ was developed to satisfy the FCC “re-farming” mandate that called for all LMR use in the VHF and UHF bands in particular, to shift to narrowband capability by January 1st, 2005. Part of the requirement of this mandate was that any technology complying with this mandate also had to have the capability to provide voice and/or data at 6.25 kHz or an “equivalent” bandwidth.

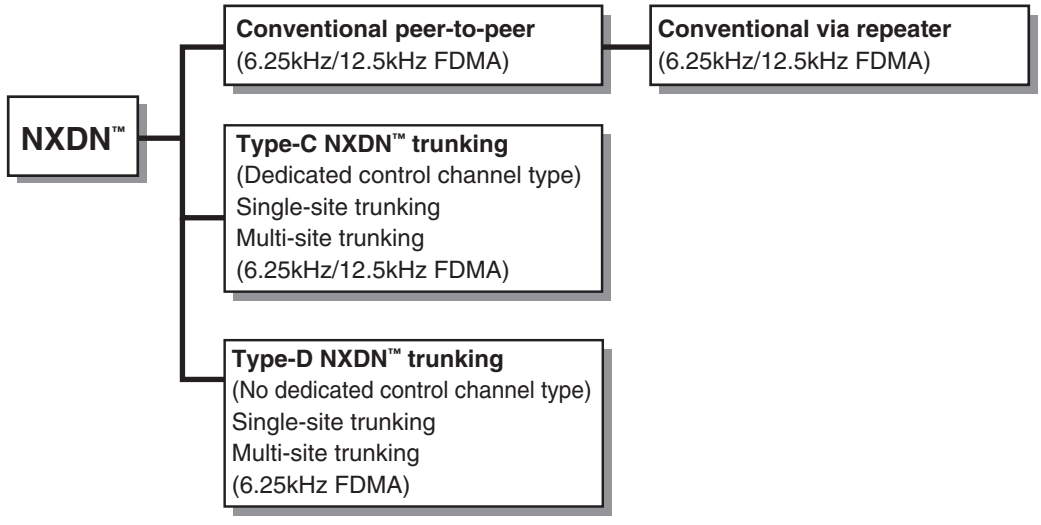
For many years it was thought that achieving 6.25 kHz bandwidth and maintaining acceptable communications quality at the same time, was a huge technical challenge at a minimum, if not technically impossible. However, research on the advances in vocoding technology and other elements essential to digital wireless communication showed that it was indeed possible to achieve communications at this bandwidth and the birth of NXDN™ was decided.

Icom and JVC KENWOOD began the collaboration in 2003 and the first NXDN™ capable conventional radio products appeared in 2006. The announcement of the NXDN™ protocol was made at IWCE 2005, which indicated that there were companies that were able to comply with the initial narrowband mandate deadline. Subsequent requests for delay of this deadline resulted in it being pushed back to 2013, but NXDN™ was ready to go, and the release went ahead.

The first products to come out were conventional radios and repeaters that had the capability of “dual-mode” from the start i.e. to operate in both digital and analog modes. While obvious now, this was an important requirement in the migration to digital in general as analog systems still had and do have many years of use. The complete replacement of an entire system in one go, is not always a feasible financial option for many users.

The NXDN™ suite of standards has grown and matured to include single and multi-site trunking solutions. The graphic below shows a simple representation of the NXDN™ standards suite structure. Enhancements already added to this are AES and DES encryption.

While primarily targeted as a solution for business and industry market segments at the beginning, the acceptance of NXDN™ worldwide has now reached a level where virtually all market segments including some public safety entities are using NXDN™.



Below is a brief timeline of the evolution of some larger NXDN™ historical milestones.

1997: The FCC announced the “re-farming” mandate for LMR VHF and UHF bands in the U.S.A.

2003: Icom Incorporated and Kenwood Corporation (Now JVC KENWOOD Corporation) made a technology alliance to develop the NXDN™ protocol

2005: NXDN™ protocol development was announced at IWCE 2005

2006: First NXDN™ products released to the market

2008: The NXDN™ Forum was established by the initial eight member companies

2009: The NXDN™ website was opened (**http://www.nxdn-forum.com/**).

2009: Five new member companies were added to the Forum.

2010: The NXDN™ Forum expanded to 16 members.

2010: An informal collaboration with the dPMR™ Association was announced.

2011: The “Type-D” NXDN™ trunking protocol was added to the standards suite.

2011: Five new member companies joined the Forum and membership increased to 21.

2011: AES and DES encryption standards were added to the standards suite.

2012: Nine new member companies join the Forum.

2012: The NXDN™ Forum website was renewed.

2012: The NXDN™ standards suite was opened.

2013: Seven new member companies join the Forum.

2014: First NXDN™ Forum booth at IWCE.

1.3 Technical specifications of NXDN™

Access Method	FDMA	
Modulation	4-level FSK	
Vocoder	AMBE+2™	
Channel Spacing	6.25 kHz	12.5 kHz
Transmission Rate	4800 bps	9600bps
Codec Rate	3600bps	7200bps
Conventional	Yes	
Trunking operation	Yes Type-C and Type-D	Yes Type-C
Digital Scrambling	Yes (15-bit/32,000 keys)	
Encryption	Yes (AES/DES)	

The basic NXDN™ hardware platform utilizes the same basic structure as analog FM radio designs with the addition of the components/circuits for the digital capability. It was the specific intention to maintain as much of current analog FM technology in the hardware design to:

- Reduce the complexity of development
- Reduce the cost of development and the resulting products
- Maintain ease in manufacture
- Reduce the probability of parts obsolescence by utilizing as many common devices as possible
- Maintain commonality in maintenance and repair
- The ability to reduce the need for specialized testing equipment

NXDN™ Trunking:

NXDN™ contains two trunking protocols within the same standards suite. For purpose of simplicity these two trunking protocols have been called NXDN™ Type-C and NXDN™ Type-D trunking.

Type-C trunking is a centralized, control channel based architecture where the trunking logic and allocation of traffic channels is done via a dedicated control channel.

Type-D trunking is a distributed logic based architecture where no control channel is used, and all channels available in the system can operate as traffic channels.

As the NXDN™ standard contains a broad spectrum of functions and the feature set of a system is determined by the manufacturer developing their system for the market needs they will serve. From this perspective, no one standard feature set can accurately be listed here, but the following could be considered to be common to most NXDN™ trunking systems of either variety.

- Single and Multi-site capability
- Individual and Group call capability
- Data features (Short text, GPS and status messaging)
- Automatic Roaming
- Maximum of up to 60,000 ID's per system
- Wide area networking capability via IP linking

Vocoder:

NXDN™ has utilized from the start, the AMBE+2™ vocoder from Digital Voice Systems, Inc. (DVSI). This vocoder is recognized as the leading low-bit rate vocoding technology and has also been widely adopted in other two-way radio standards like dPMR™, DMR, P25 Phase 1 and Phase 2 to name a few. The use of this vocoder in its "half-rate" mode is also a leading factor in achieving 6.25 kHz operation. Prior experience with P25, already considered an acceptable quality, also allowed some improvements in signal quality to be made.

Audio Quality and Coverage:

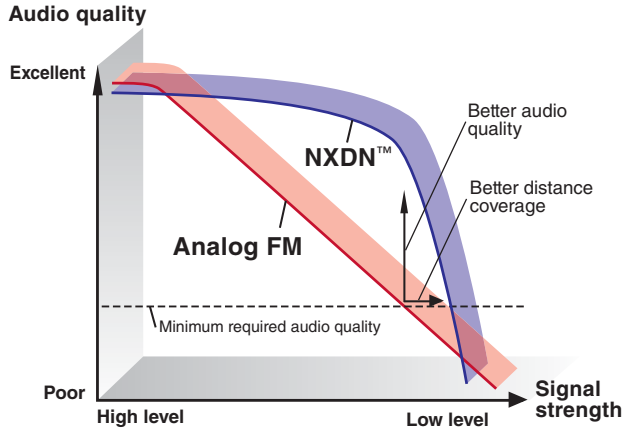
A lot of debate about whether digital audio quality is better than FM analog has gone on over the years. Most people have also seen the diagram on the below about coverage in every manufacturer's product catalogs.

It comes down to a matter of preference in many cases regarding audio quality, but the noise suppression characteristics of digital radio is superior to FM analog, and as with CD's versus LP's, it will soon be safe to say "gone are the days of that analog background noise".

Comments about "improved" coverage need to be considered carefully. The perceived gain in coverage is as the diagram shows, based on the distance a signal is able to be clearly understood or heard, within the RF signal footprint. In the case of NXDN™ versus FM analog, total RF coverage is at minimum the same, however, experience from the field indicates that the NXDN™ signal in many cases provides a wider footprint than analog FM.

For more details on specific equipment technical specifications, we advise you to refer to the respective manufacturer's product data.

Analog vs Digital Coverage



1.4 Comparison with other digital two-way radio technologies

This is a hotter debate than digital versus analog, and again there is much misleading information confusing the end user. While the NXDN™ Forum naturally endorses NXDN™ for its overall technical merits and advantages and long term benefits for the LMR industry, we also support other 6.25 kHz FDMA technologies like dPMR™.

The market has also accepted the other technologies above and many others, so it is probably correct to say that there is room for all options at this point, and that some options will gain more market acceptance than others as the shift from analog to digital progresses.

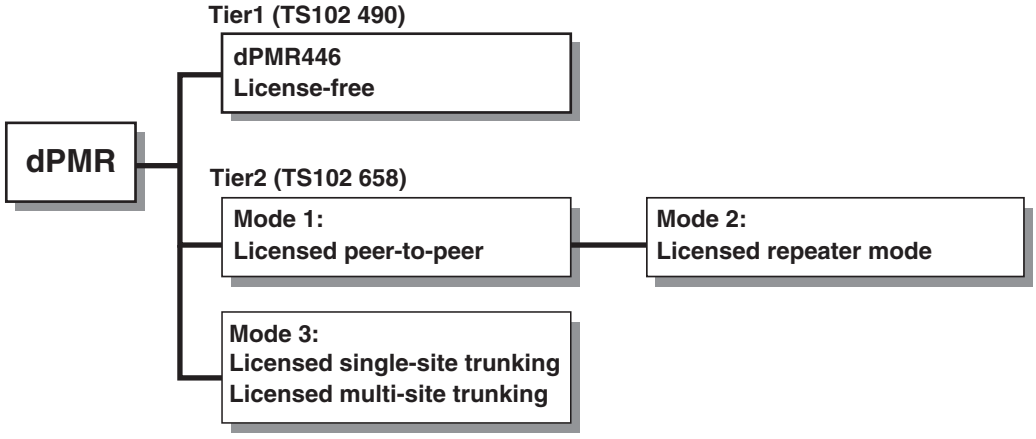
A list of the currently available digital two-way radio technologies is as below.

FDMA based	TDMA based
NXDN™	DMR
dPMR™	TETRA
P25 (Phase 1)	P25 (Phase 2)
ARIB standard T-98	PDT
ARIB standard T-102	
Tetrapol	

For the purposes of this document we will make a simple comparison between NXDN™, dPMR™ and DMR only.

dPMR™:

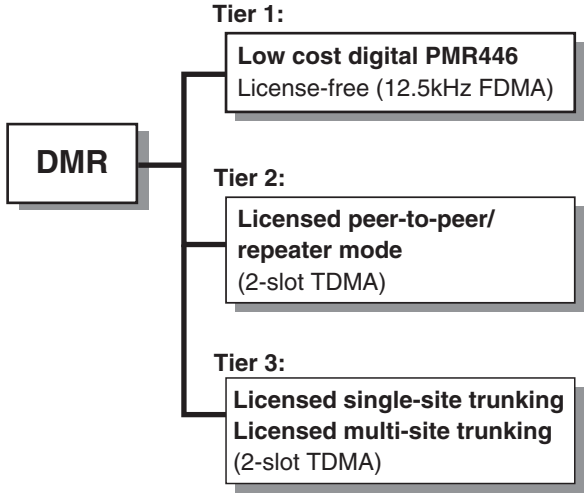
dPMR™ is a digital 6.25 kHz FDMA based protocol described in the ETSI technical standards TS 102 490 and TS 102 658. Details of what dPMR™ is and can do, can be found on the dPMR™ Association website (**http://www.dpmr-mou.org**), but the basic structure of the dPMR™ standards suite is shown in the graphic below.



As the diagram shows, dPMR™ is a full featured system capable of providing communications solutions ranging from license-free all the way up to nation-wide networks. The main difference to NXDN™ is additions of the license-free standard. The dPMR™ protocol allows for system sizes up to a potential of 1,000 sites and millions of users.

DMR:

DMR is a digital 12.5 kHz 2-slot TDMA based protocol described in the ETSI technical standard TS102 361. Details of what DMR is and can do, can be found on the DMR Association (**http://dmrassociation.org/**) website, but the basic structure of the DMR suite is shown in the graphic on the below.



As the diagram shows, DMR is also a full featured system capable of providing communications solutions ranging from license-free all the way up to nation-wide networks.

Section 2: The NXDN™ Forum:

2.1 What is the purpose of the NXDN™ Forum?

The NXDN™ Forum was founded for the following purposes, but its mission is continually expanding.

- Provide a forum for interested parties that wish to support the latest in digital two-way radio technology, and in particular NXDN™ and 6.25 kHz FDMA technology
- Participate in making and maintenance of the related NXDN™ standards
- Develop a trademark for NXDN™
- Develop and carry out interoperability testing procedures
- Ensure a minimum level of interoperability between different manufacturer's NXDN™ products
- Actively promote NXDN™ worldwide in conjunction with its members and liaise with regulatory bodies and like-minded entities in this endeavor.

A number of the goals initially set are already completed and the NXDN™ Forum is currently concentrating on interoperability and conformance testing activities and additions to the standards suite like encryption.

2.2 Who are our members?

As of the printing of this document, there are 33 members in the NXDN™ Forum. The member companies are in alphabetical order:

Member Company	Product category
Aeroflex Wichita Inc.	Radio test sets
ALTONIKA Ltd.	Radio manufacturer
Arinc	Radio systems management and test house
Anritsu Company	Radio test sets
Avtec Inc.	Dispatch consoles and applications
The Boeing Company	Test equipment
Catalyst Communications Technologies, Inc.	Dispatch consoles and applications
CML Microsystems Plc	Silicon baseband IC chips
Compliance Testing, LLC	Test house
Connect Systems Inc.	Radio manufacturer
CVDS Inc.	Recording applications
Daniels Electronics Ltd.	Infrastructure manufacturer
Etherstack	Protocol stack supplier
Eventide Inc.	Recording applications
EXACOM, Inc.	Logging recording products
General Dynamics SATCOM Technologies	Radio test sets

GME/Standard Communications Pty Ltd.	Radio manufacturer
HigherGround, Inc	Recording applications
Hoag Electronics Inc.	Radio plug-in module manufacturer
Hytera Communications Corp., Ltd.	Radio manufacturer
Icom Incorporated	Radio manufacturer
JVC KENWOOD Corporation	Radio manufacturer
RF Technology Pty Ltd.	Infrastructure manufacturer
Raven Electronics Corporation	Manufacturer and applications
Ritron Inc.	Radio manufacturer
Swissphone Telecom AG	Manufacturer and applications
Telex Radio Dispatch Group	Dispatch consoles and applications
Timco Engineering	Test house
Twisted Pair Solutions	Dispatch consoles and applications
UL LLC	Test house
Ultratech	Test house
WAVECOM ELEKTRONIK AG	Decoder software solutions
Zetron, Inc.	Dispatch consoles and applications

2.3 What competences can our members provide?

The NXDN™ Forum membership is multi-faceted and can provide almost all required products and services expected in the LMR industry. Examples are radio terminals, repeaters, applications, controllers, consoles, protocol stacks, conventional and trunking systems, silicon chips, test/measurement equipment, voice recording solutions and test lab certification.

More information on the NXDN™ Forum membership and what their businesses are about can be found here.

http://www.nxdn-forum.com/members/

For more information about the NXDN™ Forum, please also visit the website.

http://www.nxdn-forum.com/

Section 3: An FAQ about NXDN™

3.1 An FAQ about NXDN™

Q1: What are the target users of NXDN™?

A1: The uptake of NXDN™ has far exceeded the initial Business and Industry market tier it was originally aimed at. A myriad of markets categories like security, transportation, railways, construction, shopping malls, factories, taxi companies, hotels and more use NXDN™ worldwide. There has also been success in supplying NXDN™ systems to public safety entities like police forces and municipalities as well as to the military.

Q2: What are the features of NXDN™?

A2: The NXDN™ standard provides for most of the features that the analog systems supported like various call types, data communication, GPS location services, messaging and test/status features etc. For information on the specific feature sets of current NXDN™ products, it is recommended to look at individual product literature of our members.

Q3: Is there a time delay in digital communication?

A3: Yes, there is a minimal delay between the transmission and receive in digital mode due to the characteristics of encoding and decoding voice by the vocoder. This delay is not noticeable to the user unless the calling person is within hearing range. The same delay occurs with cellular phones and other digital radio technologies too.

Q4: Is there "signaling" in digital mode?

A4: Because it is digital, there is no "signaling" like CTCSS as such. However, the equivalent Selcall type functions like Individual Call or Group Call that you would utilize with signaling in analog mode, are available in digital mode too. For example, the RAN (Radio Access Number) feature acts like a CTCSS/DTCS code in analog mode.

Q5: How many RAN (Radio Access Number) codes are available?

A5: Up to 63 RAN codes are available.

Q6: Is there a digital encryption feature in NXDN™?

A6: A 15-bit digital voice scrambler is built-in as a standard feature in the NXDN™ protocol. It is not true "encryption", but does provide superior communications security compared to most standard analog voice scramblers. The NXDN™ digital voice scrambler has over 32,000 codes to program.

Q7: Is it possible to have more than a 15-bit digital scrambler?

A7: The NXDN™ specification has recently added DES and AES encryption options that will allow for high-level communications security.

Q8: What is Type-C and Type-D NXDN™ trunking?

A8: Type-C is *C*entralized (Control channel) type trunking and Type-D is *D*istributed logic trunking.

Q9: Why was Type-C and Type-D NXDN™ trunking developed?

A9: As one of the goals for NXDN™ is to become a de-facto two-way digital radio standard, it was envisioned to cater for as much of the potential market needs as possible.

Also, as NXDN™ was developed to meet the FCC mandate for narrowbanding, or in other words, a major market naturally being North America, it was recognized that both control channel and distributed logic trunking architectures were equally predominant in this market based on the analog equivalents already in deployment.

Q10: What are the licensing issues associated with NXDN™ and 6.25 kHz in general?

A10: Due to the spread of NXDN™ throughout the world and the recognition of its capabilities as a communications protocol, many national administrations have already implemented licensing rules or adopted the use of 6.25 kHz channels in their national band plans for professional radio.

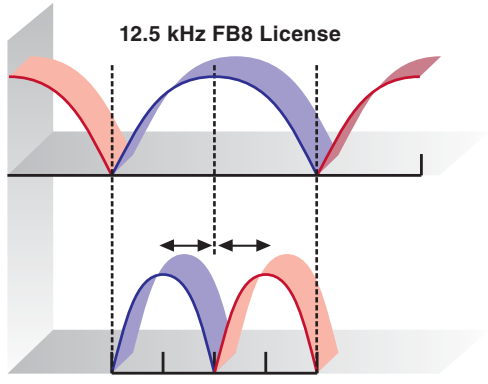
For example, the United States already over 3,000 channels dedicated as 6.25 kHz channels and the FCC has recently announced a ruling allowing licensing of 2 x 6.25 kHz channels in a 12.5 kHz channel. Frequency co-ordination entities have also proactively made recommendations for systems interference parameters and installation guidelines.

As with any radio licensing issue, enquiries to the respective administration should be made in advance if there are doubts on what can be installed etc.

Q11: What exactly are the requirements for using 2 x 6.25 kHz in a 12.5 kHz channel in the USA?

A11: Again we recommend that consultation with frequency coordinators and/or licensing authorities is done in advance, but the basic guidelines are as follows.

On January 5, 2012, the FCC Wireless Telecommunications Bureau and Public Safety and Homeland Security Bureau approved licensing two channels of 4 kHz occupied bandwidth with their center frequencies offset by 3.125 kHz above and below the center frequency of a designated 12.5 kHz frequency.



Non standard pairs offset 3.125 kHz

Specific procedures and conditions apply:

- Emission designations 4K00F1E, 4K00F1D, 4K00F2D and 4K00F7W (NXDN™)
- 450-470 MHz band listed within FCC Rule Sections 90.20 and 90.35
- 12.5 kHz (FB8) exclusive use channels pursuant to FCC Rule Section 90.187
- Normal rules for a mobile “pair”; separated by 5 MHz pursuant to Section 90.173(i)

Note: for a copy of the FCC letter, please click here:

http://www.fcc.gov/document/non-standard-frequency-pairs-450-470-mhz-band

Q12: How does this actually work in practice?

A12: The following is a general description of the logic.

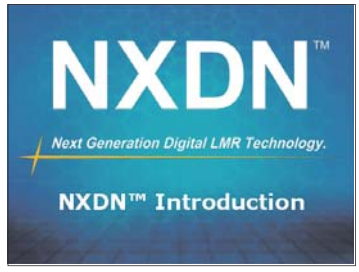
- The “authorized bandwidth” of a narrowband channel is 11.25 KHz
- The “authorized bandwidth of a ultra narrowband signal is 6 kHz
- The “occupied bandwidth” of an NXDN™ 6.25 kHz signal is 4 kHz
- Two NXDN™ signals (4kHz each) meet the 12.5 kHz emission mask without interfering with a neighbor or each other
- A licensee is able to maintain its current bandwidth and not “bleed over” into adjacent spectrum
- A frequency coordinator will submit license applications listing both the 12.5 kHz and non-standard channel centers

Q13: There have been many comments about increased interference form 6.25 kHz systems. What is the real story here?

A13: There was a lot of misrepresentation about the interference concerns initially. However, put simply, as with analog equipment to date, any NXDN™ radio product MUST comply with national type approval regulations or they cannot be legally sold. Considering the vast numbers of NXDN™ radios already in the market as stated in this document, the most honest answer would be that NXDN™ would cause no more interference than any other two-way radio technology.

Section 4: Other Resources:

4.1 An introduction to NXDN™



This introduction gives a brief overview of NXDN™ as a simplified supplement to this document.

http://www.nxdn-forum.com/resources/

4.2 NXDN™ document resources

a) FDMA versus TDMA Information Paper

This document can be found at the following link to the NXDN™ Forum website. It describes the general differences between FDMA and TDMA.

http://www.nxdn-forum.com/resources/

b) Whitepaper: NXDN™

This document can be found at the following link to the NXDN™ Forum website. It gives an overview on FDMA digital with some technical details and other information.

http://www.nxdn-forum.com/resources/

c) Product Literature:

Please refer to the respective member websites on the various NXDN™ products available now

4.3 FCC narrowbanding information

While this information has been around for some years now, the deadline of January 1st, 2013 for business and industry LMR systems in the VHF and UHF bands has passed. It is advised to familiarize yourself with this mandate to ensure you are prepared.

4.4 Frequency coordination information

The Land Mobile Communications Council website provides a lot of information for North American system operators in regards to narrowband frequency coordination.

http://lmcc.org/filings.html

For other territories, it is recommended to consult with your local licensing authority.

Disclaimer

This document has been prepared by the NXDN™ Forum as a reference document about the NXDN™ digital two-way radio protocol. The information in this document has been carefully checked, and is believed to be correct and accurate. However, the NXDN™ Forum assumes no responsibility for inaccuracies or mistakes.

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