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# EUROPEAN VOLUNTEER RESCUERS MANUAL

An expanded manual
for **volunteer rescuers**

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# EMERGENCY COMMUNICATIONS AND RADIO SYSTEMS IN RESCUE OPERATIONS

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# Chapter 1: Introduction and Operational Context

## 1.1 Purpose of the Chapter

This chapter aims to present the operational context and objectives of communications systems used during rescue operations.
Communications are a fundamental component of emergency response. They enable command, coordination, safety, and situational awareness across all levels of an operation. In complex emergencies, particularly those involving multinational teams, communications often represent the primary limiting factor of operational effectiveness.
This chapter establishes the conceptual framework used throughout the document and defines the operational approach adopted for European rescue operations.

## 1.2 Context of Modern Rescue Operations

Rescue operations today are increasingly characterized by:
large-scale and complex disasters,
simultaneous deployment of multiple response actors,
multinational and multi-agency environments,
degraded or destroyed infrastructures,
strong time pressure and high-risk conditions.
In such contexts, the ability to establish, maintain, and manage

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communications directly influences the success of the mission and the safety of responders.

# 1.3 Role of Communications in Emergency Response

Communications fulfill several critical operational functions:
transmission of orders and instructions,
coordination between teams and sectors,
reporting from the field to command levels,
dissemination of safety-related information,
support to decision-making processes.
They are not limited to technical exchanges but constitute a command tool that structures the entire operation.

# 1.4 Operational Constraints and Challenges

Communication systems must operate under severe constraints, including:
absence of pre-existing infrastructure,
electromagnetic interference,
environmental obstacles (rubble, fire, terrain),
limited power availability,
language and cultural barriers.
These constraints require communication solutions that are robust, adaptable, and simple to use.

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# 1.5 European and International Operational Framework

European rescue operations are conducted within recognized frameworks such as:
the EU Civil Protection Mechanism (UCPM),
INSARAG Guidelines,
bilateral and multilateral agreements between states.
These frameworks impose requirements in terms of:
interoperability,
coordination,
information sharing,
safety standards.
Communication systems must therefore support these requirements.

# 1.6 Objectives of a Communication System in Rescue Operations

From an operational perspective, a communication system must:
ensure responder safety,
support effective command and control,
enable coordination between actors,
remain functional in degraded environments,
integrate different technologies coherently.
These objectives guide the selection and deployment of all communication means described in the following chapters.

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# 1.7 Structure of the Document

This document is organized as follows:
Chapter 1: Introduction and operational context
Chapter 2: Operational communication requirements
Chapter 3: Analog radio communications
Chapter 4: Digital radio communications
Chapter 5: Satellite communications
Chapter 6: Broadband networks (4G/5G)
Chapter 7: Integrated architecture and redundancy
Chapter 8: Training, standards, and European recommendations
Each chapter adopts a field-oriented, operational approach, aligned with European and international best practices.


*Figure 1: Communication Systems in Rescue Operations*

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# Chapter 2: Operational Communication Requirements During a Rescue Operation

## 2.1 General Principles

During a rescue operation, communications are not merely a logistical support function but a critical operational capability, on the same level as command, logistics, or safety.
Any failure in communications immediately results in a degradation of operational effectiveness and an increased risk to responders.
Communication systems must therefore be designed not according to available technologies, but based on actual field requirements, in environments often characterized by:

- destroyed or saturated infrastructure,
- noisy, dusty, and unstable environments,
- the coexistence of multiple national and international actors,
- high stress levels and severe time constraints.

## 2.2 Responder Safety

The primary objective of communications is the protection of deployed teams.
Communications must enable:

- continuous contact between teams and their leaders,
- immediate alerting in case of danger,

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- approximate localization of deployed teams,
- rapid dissemination of withdrawal or evacuation orders.

In operational terms, this requires:

- simple-to-use equipment,
- ergonomics compatible with PPE,
- clear, direct, and prioritized voice communications,
- radio procedures that are known and regularly practiced during training.

In this context, reliability always takes precedence over technological sophistication.

# 2.3 Command and Control (C2)

Communications are the primary tool of Command and Control (C2).

They must enable:

- downward transmission of orders,
- upward reporting from the field,
- coordination between sectors, teams, and functions,
- rapid adaptation of the operational maneuver.

An operational communication system must be structured according to the command organization:

- team / buddy level,
- sector level,
- forward command post level,
- national or international coordination level.

A lack of radio network structuring quickly leads to channel saturation and loss of situational awareness.

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# 2.4 Multi-Agency and Multinational Coordination

In a European or international context, rescue operations frequently involve:

- multiple national services,
- specialized teams (USAR, medical, fire),
- NGOs,
- local authorities,
- and sometimes military forces in support.

Communications must therefore:

- enable a minimum level of interoperability,
- remain understandable despite language barriers,
- rely on simple, shared procedures,
- include fallback solutions in case of system incompatibility.

In practice, this requires:

- common channels or communication gateways,
- clear radio usage rules,
- a clearly identified communications coordination role within the command post.

# 2.5 Operational Information Management

Beyond voice communications, modern operations require the circulation of operational information such as:

- team positions,
- situation reports,
- images or video,

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- data from drones or robots,
- meteorological or environmental information.

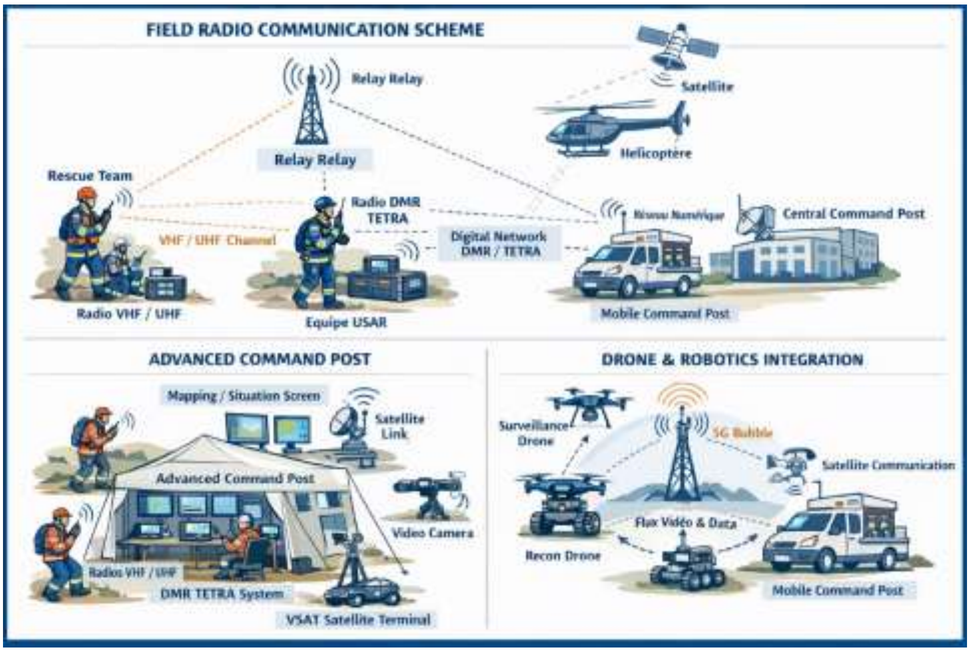


*Figure 2: Field Radio Communication Scheme*

However, in the field, voice communication remains the priority.
Data transmissions must never degrade the ability to communicate by voice.
A fundamental principle must be respected:
Data communications complement voice radio; they do not replace it.

# 2.6 Resilience and Degraded Mode Operations

Communication systems must be designed to operate:

- with partially degraded resources,
- without infrastructure,
- under energy constraints,
- over extended durations.

This requires:

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- autonomous solutions,
- redundancy of means,
- clear fallback procedures,
- the ability to revert to simple modes (analog radio).

Resilience depends as much on operational doctrine as on technology.

# Chapter 3: Analog Radio in Rescue Operations

## 3.1 Operational Role of Analog Radio

Analog radio (VHF/UHF) remains a cornerstone of operational communications, despite the evolution of digital technologies.

In the field, it is often:

- the first communication means available,

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- the last one still operational in degraded conditions,
- the fallback solution when complex systems fail.

Its simplicity constitutes a **major operational advantage**.

*Figure 3: Analog Radio System kit*

*Figure 4: Mobile Analog Radio system*

# 3.2 Preferred Operational Contexts

Analog radio is particularly suited for:

- close-range communications,
- operations in unstable environments (collapse, fire, forest),
- initial response phases,
- operations requiring immediate deployment.

It is widely used:

- by field teams,
- for buddy-to-team leader communications,

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- as a safety network.

# 3.3 Operational Advantages

The main operational advantages are:

- **robustness**: low sensitivity to partial degradation,
- **simplicity**: rapid training, intuitive procedures,
- **autonomy**: no dependency on a network core,
- **de facto interoperability**: frequent compatibility between local actors.

In chaotic environments, these characteristics are decisive.

# 3.4 Limitations and Constraints

Analog radio nevertheless presents significant limitations:

- lack of native encryption,
- limited capacity (one channel = one transmission),
- variable audio quality,
- rapid saturation under heavy traffic.

In multinational contexts, frequency and regulatory differences may further limit its use.

# 3.5 Operational Best Practices

To ensure effective use of analog radio, it is essential to:

- limit the number of messages,
- use clear and standardized phraseology,
- avoid unnecessary communications,

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- clearly identify transmitters,
- plan backup channels.

Radio discipline is a key success factor.

# 3.6 Role of Analog Radio in a Global Architecture

Analog radio should not be considered obsolete, but rather as:

- a safety layer,
- a fallback net,
- a reliable means in degraded mode.

It integrates into a broader architecture alongside digital radios, satellite communications, and broadband networks.


*Figure 5: Operational Advantages and Limitations of Analog Radio*

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# Chapter 4: Digital Radio Communications in Rescue Operations

*(DMR, TETRA, P25 - Operational Approach)*

## 4.1 Operational Role of Digital Radios

Digital radio systems now form the **backbone of structured communications** during large-scale national or international rescue operations.

They are primarily used for:

- command and control,
- inter-agency coordination,
- sector management,
- links between command posts.

Unlike analog radio, digital systems are designed to handle higher traffic volumes, with improved priority and user management.

## 4.2 Fundamental Differences from Analog (Field Perspective)

From an operational standpoint, the difference lies not in technology but in **usage**.

Digital radio enables:

- multiple simultaneous communications on the same channel,
- more consistent audio quality,

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- better organization of communication groups,
- advanced functions (priority, emergency calls).

However, it requires:

- prior configuration,
- strict discipline,
- partial dependency on infrastructure.

## 4.3 Organization of Digital Networks in Operations

### 4.3.1 Talk Groups

Digital radios are organized into **talk groups** corresponding to the operational structure:

- command group,
- sector groups,
- functional groups (logistics, medical, safety),
- inter-agency coordination group.

This organization reduces radio saturation, provided it is clearly defined before deployment.

### 4.3.2 Priority Management

Digital systems allow the assignment of:

- traffic priorities,
- privileged network access,
- emergency call functions.

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In critical situations, a sector leader or command can interrupt lower-priority traffic to transmit a vital message.

# 4.4 Use in Multinational and European Contexts

In European operations, digital radios are widely deployed but rarely homogeneous.
Field constraints include:
coexistence of different standards (TETRA, DMR, P25),

- encryption incompatibilities,
- national communication security policies,
- regulatory restrictions on frequencies.

In practice, digital networks are often used:

- internally within each team,
- at national command post level,
- via gateways or relays for international coordination.

# 4.5 Communication Security

Digital radios provide integrated encryption capabilities, essential to:

- protect sensitive information,
- prevent interception,
- secure command data.

However, in the field, encryption can become a constraint:

- inability to interoperate with other actors,
- complexity of key management,

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- deployment delays.

A balance must be found between **security and interoperability**.

# 4.6 Deployment in Degraded Environments

Digital systems generally require:

- repeaters,
- base stations,
- stable power supply.

If infrastructure is destroyed, several solutions exist:

- vehicle-mounted mobile repeaters,
- deployable temporary stations,
- autonomous “tactical cell” networks.

These capabilities must be anticipated during planning.

# 4.7 Operational Limitations of Digital Radios

Despite their advantages, digital radios present limitations:

- dependency on infrastructure,
- configuration complexity,
- abrupt loss of communication at coverage limits,
- sensitivity to network saturation if poorly planned.

In the field, a poorly deployed digital radio is often **less reliable than a simple analog radio**.

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# 4.8 Complementarity with Analog Radio

In a realistic operational architecture:

- analog radio is used for proximity and safety,
- digital radio for coordination and command,
- both systems coexist and complement each other.

No serious operation relies on a single communication type.

# 4.9 Operational Recommendations

For effective use of digital radios in operations:

- clearly define communication groups,
- limit the number of active talk groups,
- train leaders in radio management,
- always plan an analog fallback.

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*Figure 6: Digital Radio Operational Outcomes*

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# Chapter 5: Satellite Communications in Rescue Operations

## 5.1 Operational Role of Satellite Communications

Satellite communications play a **strategic role** in rescue operations when terrestrial communication infrastructures are unavailable, destroyed, or overloaded.

They provide:

- long-range communication capability,
- international connectivity,
- command-level data and voice links,
- independence from local infrastructure.

Satellite systems are not intended for mass field communications but for **command, coordination, and external liaison**.

## 5.2 Typical Operational Use Cases

Satellite communications are primarily used for:

- links between the field command post and national authorities,
- coordination with international organizations (EU, UN, INSARAG),
- transmission of situation reports and operational data,
- redundancy for critical communications.

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They are particularly relevant during:

- large-scale disasters,
- remote or isolated environments,
- cross-border or multinational operations.

# 5.3 Types of Satellite Systems Used in Operations

## 5.3.1 Satellite Telephony

Satellite phones provide:

- voice communications,
- SMS capability,
- high reliability.

They are widely used by:

- mission team leaders and squad leaders,
- liaison officers,
- coordination staff.

Their simplicity makes them suitable for rapid deployment.

## 5.3.2 Broadband Satellite Terminals

Portable or vehicle-mounted satellite terminals enable:

- internet access,
- email communication,
- video conferencing,

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- data transmission (images, GIS, reports).

These systems support the **operational planning and coordination functions** at command post level.

*Figure 7: Mini-Starlink (with 2 batteries)*

*Figure 8: BGAN with a radio relay*

*Figure 9: STARLINK System*

# 5.4 Advantages of Satellite Communications

Key operational advantages include:

- global coverage,
- autonomy from local networks,

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- rapid deployment,
- high reliability under extreme conditions.

Satellite systems are often the **only viable communication link** during the initial phase of a disaster response.

## 5.5 Limitations and Constraints

Despite their importance, satellite communications present constraints:

- limited bandwidth,
- latency affecting real-time applications,
- weather sensitivity (rain fade),
- dependency on clear sky visibility,
- high operational costs.

They must therefore be used selectively and managed carefully.

## 5.6 Integration into the Communication Architecture

Satellite communications should be integrated as:

- a command-level backbone,
- a redundancy layer,
- a gateway to external networks.

They must not replace local tactical communications but **support the overall system**.

## 5.7 Operational Best Practices

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Effective satellite communication use requires:

- trained operators,
- bandwidth prioritization,
- predefined usage rules,
- power management planning.

Satellite resources must be protected from saturation by non-essential traffic.

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# Chapter 6: Broadband Networks (4G / 5G) in Rescue Operations

## 6.1 Operational Context of Broadband Use

*Figure 10: Radio Relay (5G/Satellite)*

4G and 5G networks provide **high-bandwidth communication capabilities** that enable advanced operational functions such as:

- real-time video,
- drone data transmission,
- GIS and mapping,
- collaborative command tools.

They are increasingly used in modern rescue operations.

## 6.2 Dependence on Infrastructure

Unlike radio and satellite systems, broadband networks rely on:

- cellular infrastructure,

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*Figure 11: Full communication kit*

- backhaul connectivity,
- power supply.

In disaster environments, these elements are often:

- damaged,
- overloaded,
- partially operational.

This limits their reliability during early operational phases.

# 6.3 Tactical Deployment Solutions

To mitigate infrastructure dependency, several solutions exist:

- deployable mobile base stations,
- vehicle-mounted LTE/5G cells,
- aerial relays using drones or balloons,
- hybrid satellite-cellular systems.

These solutions extend coverage and restore connectivity locally.

# 6.4 Operational Uses of 4G / 5G

Broadband networks are mainly used for:

- command post applications,
- situational awareness tools,
- transmission of images and video,
- coordination between command elements.

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They are not suited for primary life-safety voice communications.

# 6.5 Role of 5G in Future Operations

5G introduces new capabilities:

- low latency,
- network slicing,
- support for massive IoT,
- improved reliability for data streams.

These features are promising for:

- robotics,
- autonomous systems,
- sensor networks.

However, 5G remains **highly infrastructure-dependent**.

# 6.6 Operational Limitations

Broadband networks face several operational constraints:

- high energy consumption,
- complex deployment,
- cybersecurity risks,
- dependency on skilled technical personnel.

Their use must be carefully planned and controlled.

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*Figure 12: Robot with mini-starlink*

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# Chapter 7: Integrated Communication Architecture and Redundancy

## 7.1 Principle of Layered Communications

An effective operational communication system is based on a **layered architecture**, combining multiple technologies.
Each layer fulfills a specific role:

- analog radio: proximity and safety,
- digital radio: coordination and command,
- satellite: strategic and international links,
- broadband: data and situational awareness.

No single system is sufficient on its own.

## 7.2 Redundancy as a Core Requirement

Redundancy is essential to ensure:

- continuity of command,
- responder safety,
- mission success.

Redundancy must exist:

- between technologies,

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- between frequencies,
- between power sources.

Operational redundancy is as much procedural as technical.

# 7.3 Fallback Procedures

All teams must be trained to:

- recognize communication failures,
- switch to backup systems,
- apply degraded-mode procedures.

Fallback procedures must be:

- simple,
- documented,
- regularly exercised.

# 7.4 Role of the Communication Officer

A dedicated communication officer is essential to:

- manage network configuration,
- allocate resources,
- monitor traffic,
- resolve incidents.

This role is critical in large or multinational operations.

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*Figure 13: Integrated Communication Architecture*

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# Chapter 8: Training, Standards, and European Recommendations

## 8.1 Training as a Key Success Factor

Technology alone does not guarantee effective communications.
Training must cover:

- normal operations,
- degraded modes,
- stress conditions,
- multinational environments.

Regular exercises are indispensable.

## 8.2 Alignment with INSARAG and EU Frameworks

Communication systems must align with:

- INSARAG Guidelines,
- EU Civil Protection Mechanism (UCPM),
- national doctrines.

This alignment enhances interoperability and credibility.

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# 8.3 Recommendations for European Projects

European projects should:

- prioritize operational validation,
- involve end-users early,
- test solutions in realistic conditions,
- avoid technology-driven approaches.

The goal is to deliver **usable, reliable, and interoperable systems**.

# 8.4 Final Conclusion

Communications are a **core operational capability** in rescue operations.
Their effectiveness depends on:

- realistic design,
- layered architecture,
- trained personnel,
- strong operational discipline.

European projects must translate innovation into **tangible operational value**, improving coordination, safety, and efficiency across borders.

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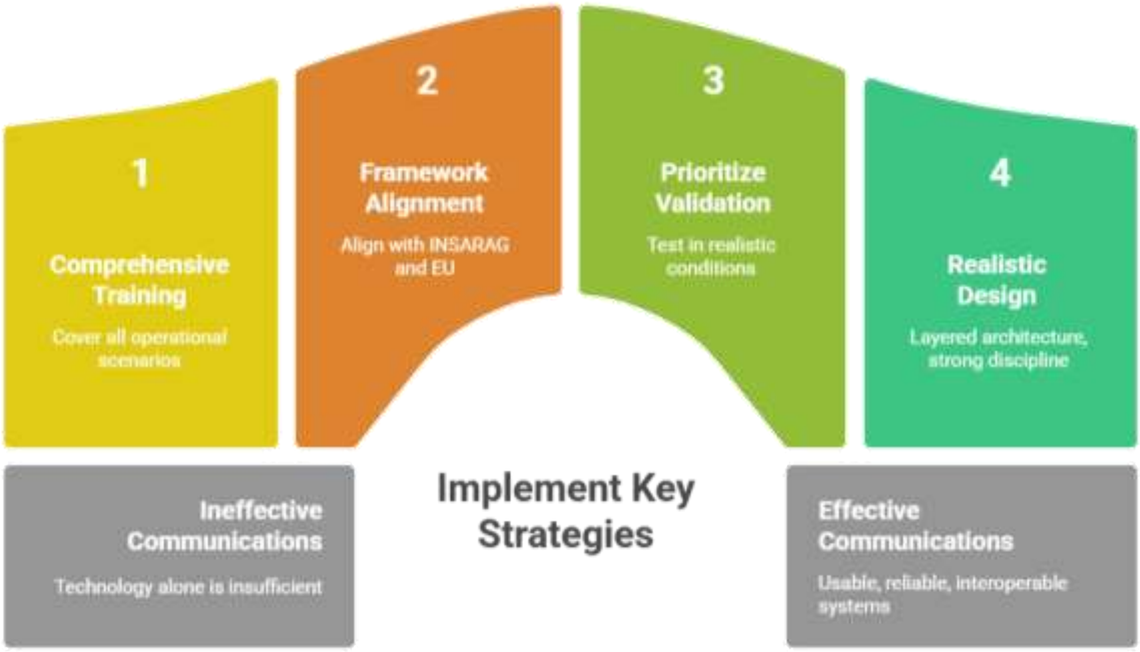


*Figure 14: Enhancing Rescue Communications*

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