



# GES 400 MR Series

 MR Conditional Systems

User Manual



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**IMPORTANT NOTICE:** The GES 400 MR and GES 410 MR products are sold for strictly research purposes and are not medical devices in the United States. As such these products cannot be used for medical purposes such as the diagnosis, treatment, cure, mitigation, or prevention of diseases.

The GES 400 MR and GES 410 MR products are CE marked in conformity with the European Medical Device Directive. Information on clearance status in other countries is available upon request.

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# Preface

Welcome to the MR-conditional Geodesic EEG System™ 400 MR (GES MR) Series systems from Electrical Geodesics, Inc. (EGI). GES MR systems work within the magnetic resonance (MR) environment to allow the simultaneous acquisition of electroencephalographic (EEG) and functional magnetic resonance imaging (fMRI) data. The components of GES MR systems, including the HydroCel Geodesic Sensor Nets™ (HC GSNs, or Nets) and the Net Amps™ (NA) amplifiers, have been specifically designed to significantly reduce the EEG and MRI systems' impact on each other by minimizing and attenuating contrary signals and artifacts.



**CAUTION:** Only MR-trained personnel should work with this equipment and only equipment labeled **MR safe** or **MR conditional** should enter the specified MR environment. Adhere to all precautions given in the "Safety and Use Conditions" chapter.

For all safety and use conditions for using the GES system *outside* of the MR environment, refer to the GES 400 series manual (8100400).

## GES MR System Models

**Table P-1.** Current models of the GES MR system

System	Amplifier	Sampling Rate*	Nets
<b>GES 400 MR</b>	Net Amps 400 (NA 400)	8 Ksps	all HC GSN MRs
<b>GES 410 MR</b>	Net Amps 410 (NA 410)	20 Ksps	all HC GSN MRs

\*Sampling rates are software dependent. Net Station allows 1 Ksps and Amp Server Pro SDK facilitates up to the full sampling rate capability of the amplifiers.

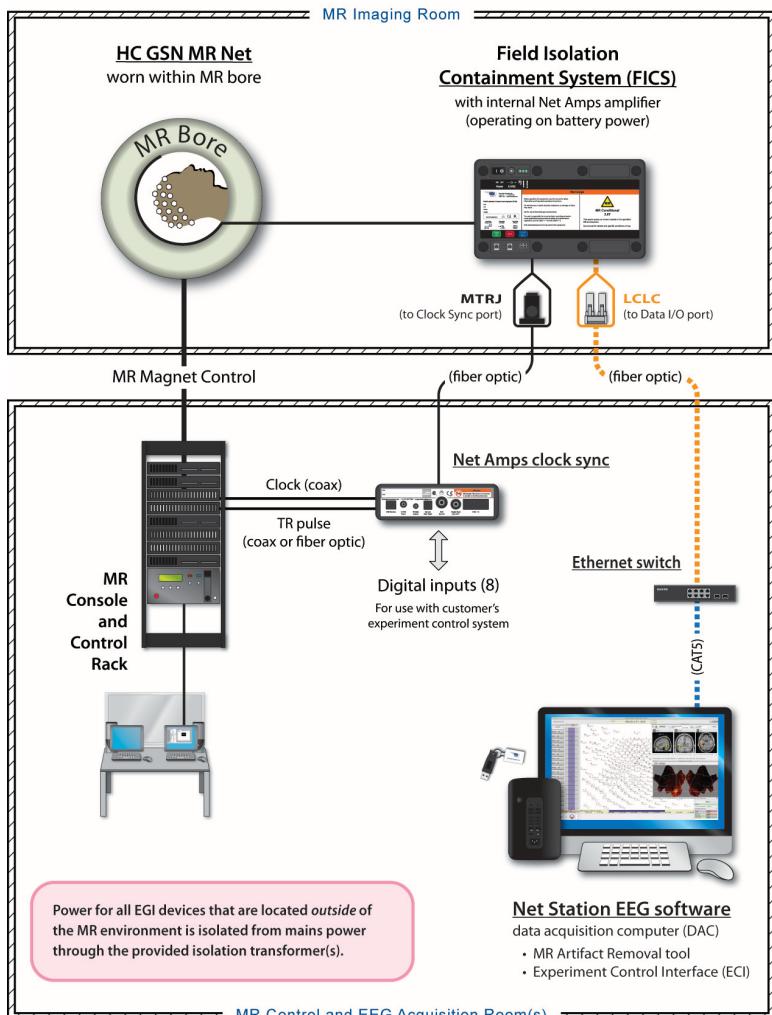
**Table P-2.** Parts list for typical GES MR systems

Part	Qty	Mfr	Mfr P/N	EGI P/N
<b>Amplifier</b>				
<b>Net Amps 400</b> (NA 400)	1	EGI		4608880 (256 chs) 4606168 (128 chs) 4606358 (64 chs) 4603285 (32 chs)
<b>Net Amps 410</b> (NA 410)				4608884 (256 chs) 4606172 (128 chs) 4606362 (64 chs) 4603289 (32 chs)
<b>Other system components</b>				
<b>Field Isolation Containment System (FICS) enclosure</b>	1	EGI		4609069 (256 chs) 4602986 (128 chs)
<b>HC GSN MR</b>	1	EGI		Refer to the HC GSN manual
<b>Net Station (NS) software</b> (includes the MR Artifact Removal waveform tool)	1	EGI		3104200
<b>HASP key</b>	1	Safenet	YWRGC	6158560
<b>Net Amps Clock Sync</b>	1	EGI		4608295
<b>Ethernet switch</b>	1	Black Box	LGB2008A-R2	6156363
<b>Isolation transformer</b>	1	Toroid	ISB-060M	6156331
<b>GES external power supply</b>	1	EGI		4603986
<b>Documentation</b>				
<b>GES MR manual</b>	1	EGI		8100401
<b>NS manual</b>	1	EGI		version dependent
<b>HC GSN manual</b>	1	EGI		version dependent
<b>EEG/fMRI placard</b>	1	EGI		8402100
<b>Optional application</b>				
<b>GeoSource</b>	1	EGI		4602001

**Note:** This parts list assumes a typical system. Your system components may differ, if you have upgraded or expanded your system.

# Typical GES MR System

GES MR systems operate within the MR environment to acquire simultaneous EEG and fMRI data.



**WARNING:** For all EGI system equipment warnings, cautions, and conditions for use, refer to the "Safety and Use Conditions" chapter of this manual.

**Figure P-1.** Core components of a typical EEG-fMRI GES MR system

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# About This Manual

This manual provides concise information for using the GES MR system to display and record EEG data within the MR environment. ***It assumes a working proficiency with EEG and computer systems.***

**Note:** The term *patient* is used to refer to subjects, participants, or patients.

An EGI support or authorized engineer will install and configure your EGI system, including all connections required for its operation. At the time of initial installation, the EGI support or authorized engineer will also train relevant staff in its operation. At any time you have additional questions or wish retraining, contact EGI Technical Support (Table P-3).

## Typographic Conventions

- *Italics* are used for definitions or newly introduced terms.
- ***Boldface italics*** are used for important concepts or for special emphasis.
- **Boldface** is used for command paths (for example, **File > Open**).

## Warnings, Cautions, and Notes

The following are used to convey important information:



**WARNING:** Warnings provide important information that, if unheeded, could result in serious physical injury, death, or equipment damage.



**CAUTION:** Cautions provide important information that, if unheeded, could hinder the use of a product, feature, or procedure, or result in physical injury or equipment failure.

**Note:** Notes provide clarifying information about a product, feature, or procedure.

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# Support, Repairs, and Documentation

If you have a question, please:

- For *urgent issues during acquisition*, contact EGI immediately.
- For *nonurgent issues*, do the following before contacting EGI:
  - **Isolate the problem.** Try to repeat and define the problem.
  - **Document the problem.** Carefully record the sequential details of the problem.
  - **Report the defined problem.** Contact EGI.

**Table P-3.** EGI contact information

<b>EGI Technical Support web page</b>	www.egi.com/support
<b>Email Technical Support</b>	supportteam@egi.com
<b>Email Sales</b>	orderdesk@egi.com
<b>Telephone</b>	+1.541.687.7962
<b>Fax</b>	+1.541.687.7963
<b>Address</b>	Electrical Geodesics, Inc. (EGI) 500 E 4th Avenue, Suite 200 Eugene, OR 97401 USA





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# 1. Safety and Use Conditions

For all safety and use conditions for using the GES system *outside* of the MR environment, refer to the GES 400 series manual (8100400).

Do not operate your GES MR system ***until you are fully trained and understand*** all warnings, cautions, and conditions for use provided in EGI's manuals for the components of your GES system. If you have any questions, contact EGI Technical Support (Table P-3).



**WARNING:** All EGI system components must be installed and configured by an EGI support or authorized engineer. Deviating from the supported configuration or running the system with non-EGI-approved components attached can cause hazards or unexpected performance.

Note that the information in this manual is subject to change, without notice. The manufacturer declines responsibility for the safety, reliability, and performance of EGI system components, if not used in compliance with EGI documentation.

## 1.1 Intended Use

Geodesic EEG System™ 400 MR Series systems are intended to measure and record the electrical activity of the brain. They can be used on adults, children, and infants.

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## 1.2 Features

- ADAPT™ technology for on-board computing and remote updates
- Dual-purpose Net Amps amplifiers usable both inside and outside the MR environment
- Nonmagnetic, battery operated FICS amplifier subsystem usable inside the MR imaging room
- Two ECG channels to facilitate ballistocardiogram attenuation
- Data acquisition synchronized with MRI gradient pulses
- Easy application of HC GSN MR Nets with saline solution
- HC GSN MR Net electrodes with internal SAR mitigation/protection
- 24 bit A/D conversion
- Fiber optic signal input and output for optimal digital bandwidth and safety isolation, including:
  - Ethernet data and control with Net Station
  - Proprietary digital I/O, MR clock, and TR sync
- Vertex referenced inputs
- 4 kV patient isolation to mains ground and 1.5 kV isolation mains to mains ground
- Choice of sampling rates (see Table P-1)
- Full range of channel counts (32 to 256)

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## 1.3 Conditions for Use

### 1.3.1 Environmental Conditions for Transport and Storage

**Table 1-1.** Environmental conditions for the transport and storage of GES MR components

<b>Shipping temperature</b>	0° to 47°C (32° to 116°F)
<b>Storage temperature</b>	-10° to 50°C (14° to 122°F)
<b>Shipping humidity</b>	5% to 95% noncondensing
<b>Shipping altitude</b>	11,500 m (37,700 ft) maximum

### 1.3.2 Environmental Conditions for Use

For EMC declarations, see Appendix A.

**Table 1-2.** Environmental conditions for the use of GES MR components

<b>Operating temperature</b>	10° to 35°C (50° to 95°F)
<b>Relative operating humidity</b>	5% to 95% noncondensing
<b>Operating altitude</b>	3,000 m (9,842 ft) maximum

### 1.3.3 Site Requirements for Location and Use

**Table 1-3.** Site requirements for the location and use of GES MR components

<b>Location</b>	For indoor use only
<b>Surface Area</b>	102 x 150 cm (40 x 59 in.)
<b>Ventilation Clearance</b>	7.62 cm (3 in.)

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### 1.3.4 System Power

**Table 1-4.** Nominal power values for GES MR components

Device	Rated Power Dissipation (watts)
<b>FICS</b>	9
<b>NA 400 series amplifier</b>	30
<b>Mac Pro desktop computer</b>	1,150
<b>Mac 27-inch display</b>	250
<b>Dell computer</b>	500
<b>Dell 17-inch display</b>	200

### 1.3.5 GES MR Electrical Specifications

**Table 1-5.** Electrical specifications for GES MRs

<b>Maximum input signal amplitude</b>	$\pm 200$ mV
<b>System input bandwidth</b>	0 to 285 Hz (3 dB)
<b>System dynamic range</b>	$\geq 115$ dB

### 1.3.6 System Contraindications

No contraindications for the use of GES MR systems are known to exist.

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### 1.3.7 Certifications and Classifications

For all current EGI regulatory certifications, including CE declarations, go to [www.cgi.com](http://www.cgi.com) or contact EGI Technical Support (Table P-3).

This medical equipment is certified to the following:

- CAN/CSA C22.2 No 601.1-M90 (Safety of Medical Electrical Equipment, Part I: General Requirements for Safety)
- CSA 601.1 Supplement 1:1994 (Requirements for Safety)
- CSA 601.1 Amendment 2:1998
- CAN/CSA C22.2 No 60601-2-26:04 (Particular Requirements for the Safety of Electroencephalograph)
- UL Standard No 60601-1 (1<sup>st</sup> Edition) (Safety of Medical Electrical Equipment, Part I: General Requirements for Safety)
- IEC 60601-2-26:2002 (Particular Requirements for the Safety of Electroencephalograph)
- The GES 400 MR series systems carry the European CE mark

This medical equipment is classified as follows:

- Applied part: Type BF
- System: MDD Class IIa Equipment, Electrical Class I Equipment

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## 1.3.8 Rating

**Table 1-6.** Input ratings for GES MR components

Part	Input Rating
GES External Power Supply	100-240 VAC, 50/60 Hz, 1.0 A
NA 400 series amplifier (from ext pwr sup)	12 VDC, 1.5 A

## 1.3.9 Interference

It is your responsibility to ensure that your GES MR system and its components are safe and operate properly before using them.

All GES MR components have been tested and found to comply with the electromagnetic compliance limits for the Medical Device Directive 93/42/EEC (EN 60601-1-2:2007 Class A and JIS T 0601-1-2:2002). See Appendix A.

These limits are designed to provide reasonable protection against harmful interference in a typical medical installation. The equipment generates radio-frequency energy and, if not installed and used in accordance with the instructions, may cause interference to other devices in the vicinity. If this equipment does interfere with other devices, which can be determined by turning the equipment off and on, try to correct the interference by one or more of the following measures:

- Reorient or relocate the receiving device.
- Increase the separation between the equipment.
- Connect the equipment to an outlet on a different circuit than the one used by the other devices.
- Consult EGI Technical Support (Table P-3).

## 1.3.10 Symbols

The following symbols are used on GES MR components and in this manual.

**Table 1-7.** Symbols used on GES MR components and in this manual

Symbol	Description	Symbol	Description
	MR conditional		MR unsafe
	Imminent hazard		European conformity
	Potential hazard		Canadian Standards Association approval
	Electrical hazard		Manufacturer
	Type BF applied part (body protected, patient isolation)		EU authorized representative
	Interference hazard		Temperature limit 10°C to 35°C (50°F to 95°F)
	Functional earth terminal		Humidity limits
	Read product documentation (EGI and third-party mfr)		No unauthorized servicing
	Keep dry		Do not use in gas environment
	Always adhere to IEC 60601-1-1 and 60601-1-2		Do not dispose with other waste (comply with local regulations)
	Signal input		Digital inputs

Symbol	Description	Symbol	Description
	Linked		Part number
	Active		Serial number
	Locked		Power input
	Ethernet		Powered
	Clock sync		Prescription medical device

## 1.4 Safety Warnings

All EGI MR conditional equipment has been tested for MR safety based on the guidelines from ASTM F2503-05 (Standard Practice for Marking Medical Devices and Other Items for Safety in the Magnetic Resonance Environment), which is one of the international standards of the American Society for Testing and Materials (ASTM). Based on these tests (including displacement force and torque, as well as RF heating), EGI's MR conditional equipment is considered safe in the specified MR environment.

The HC GSN MR Net is the only MR conditional device that will enter the bore of a magnet. All related equipment is labeled as either MR conditional or MR unsafe to ensure that only MR conditional devices will be allowed into the specified MR environment. See the following tested use conditions.



### **WARNING:** MR Conditional 3.0T—

This system poses no known hazards in the specified MR environment. Before operating this equipment, read and understand all instructions in this manual for the specific conditions of use, safety information, and important operating instruction.

Tested to:

<b>System type</b>	cylindrical
<b>Transmit coil type</b>	head and body
<b>Static field strength</b>	3T (2.8T)
<b>Radio frequency (RF) fields</b>	126.7 MHz (123 MHz)
<b>Specific absorption rate (SAR) limit</b>	3.2 W/kg
<b>EPI sequence</b>	EPI functional (BOLD), T1 structural (MPRAGE)*
<b>Repetition time (TR)</b>	2 sec (EPI), 23 sec (MPRAGE)
<b>Flip angle</b>	80 (EPI), 10 (MPRAGE)

\*For structural scans, the image may be degraded by the presence of the HC GSN during anatomical scans.

## 1.4.1 General Safety Warnings



### **WARNING:**

- ***Always connect all GES components, except those inside the MR imaging room, to the isolation transformer.*** Never connect components directly to mains electricity supply, which may result in physical injury or equipment damage.
- ***Never deviate from supported configurations and never connect non-EGI components to the isolation transformer or to other EGI components.*** All EGI components must be installed and configured by an EGI support or authorized engineer. Deviating from the supported configurations or running the system with non-EGI components attached may result in unexpected hazards or performance due to additional loading or leakage.
- ***Use only approved equipment.*** Do not connect the GES to unauthorized equipment, as physical injury or equipment damage may result. The user is responsible for ensuring that a

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reconfigured GES meets all applicable local and national regulations for safety and performance. See IEC 60601-1.

- ***Only connect GES components, except those inside the MR imaging room, to a mains electricity supply with protective earth to avoid the risk of electrical shock or electrocution.***
- ***Do not obstruct access to any GES component, including the isolation transformer, such that it is difficult to access, difficult to operate, or results in entanglements.*** The mains disconnect (the isolation transformer's mains disconnect switch) must remain accessible.
- ***Certify all accessory equipment according to the relevant IEC standards.*** Accessory equipment connected to the digital or clock sync ports of the amplifier must be certified according to the respective IEC standards (e.g., IEC 60950 for data processing equipment and IEC 60601-1 for medical equipment). Furthermore, all configurations shall comply with the system standard IEC 60601-1-1. Any person who connects additional equipment to the signal input port or signal output port configures a medical system, and is therefore responsible for ensuring that the system complies with the requirements of the system standard IEC 60601-1-1. If in doubt, consult EGI Technical Support (Table P-3).
- ***Ensure that the environment is safe.*** The rooms where GES components are used must comply with all applicable local and national safety requirements.
- ***Position the patient and operate the GES only as described in this manual.***
- ***Do not use in flammable gas environments.***
- ***Do not use in oxygen rich environments.***
- ***Do not immerse or splash electrical equipment.*** Physical injury or equipment damage may result. If liquids are spilled on any GES electronic component, immediately disconnect it from its power source. Do not use a GES component that has suffered exposure to liquids until EGI or other qualified personnel certifies that the liquid or liquid residue has not affected device operation or patient safety.

- 
- ***Do not use the system if it has been damaged, until it has been verified to be working correctly.***
  - ***Only EGI support or authorized engineers may service this equipment.*** Hazardous mains voltage inside. Refer all servicing to EGI Technical Support (Table P-3).
  - ***Do not remove any parts, while the GES is powered.*** The GES uses potentially dangerous line voltages, which are present within some subsystem devices.

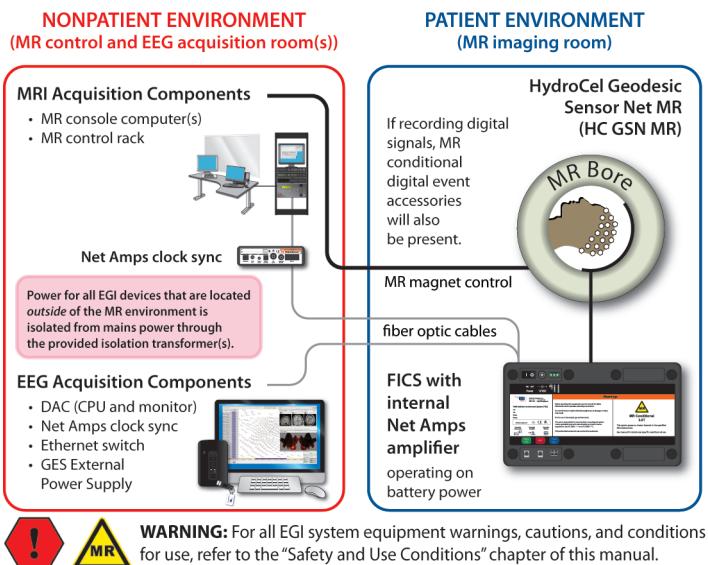
## 1.4.2 Patient Isolation



### WARNING:

- ***Connect all GES components, except those inside of the MR imaging room, only to the power mains cord supplied with the protective ground terminal.*** The presence of ground protection preserves the patient's safety, as well as your own. Check that your local electrical plant can guarantee an efficient grounding. The grounding reliability of a GES can be ensured only when used with a hospital-grade plug.
- ***Connect all GES components, except those inside of the MR imaging room, to the isolation transformer's outlets.*** Never connect the computer or other system components directly to a wall power socket, because the leakage currents in the computer can present an electrical hazard to you and the patient.
- ***Ensure electrode isolation.*** Prevent contact between the conductive part of the electrodes and other conductive parts, including the ground.

- **Maintain patient isolation within patient environment.** Never simultaneously touch the patient and any component outside of the patient area and never let patients touch any component, other than the Net that is being worn, inside or outside of the patient area.



### 1.4.3 Ground Warnings



#### WARNING:

- **Disconnect power before servicing to prevent physical injury or equipment damage.**
- **Ensure grounding reliability.** Achieved only when equipment is connected to an equivalent receptacle marked "Hospital Only" or "Hospital Grade."
- **Use a properly grounded outlet.** Otherwise, physical injury or equipment damage may result.

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## 1.4.4 Cords, Connectors, and Cables



### **WARNING:**

- **Use only approved power connections and never connect a non-GES power cord or multiple socket outlet (i.e., power strip or extension cord) to the GES.** Use only the EGI-approved power cords, connectors, cables, adapters, and multiple socket outlet that came with the GES.
- **Inspect your connectors and cables.** To reduce the risk of electrical shock, discontinue the use of worn or damaged electrical connectors and cables. Contact EGI Technical Support (Table P-3) for approved replacement parts for the country where the system is being used.
- **Never repair nondetachable cords.** Contact EGI Technical Support (Table P-3) for cord repair or replacement.
- **Do not position any cable such that it is subject to abuse.**

## 1.4.5 Disassembly



**WARNING: Do not open or disassemble the amplifier.** The interior of the amplifier contains no user-serviceable parts. In the event that the amplifier requires servicing, contact EGI Technical Support (Table P-3) for instructions on how to safely pack and return it to EGI for evaluation and servicing.

## 1.4.6 Lightning



**WARNING:** System isolation is designed to protect the patient even if a high-voltage source is accidentally applied to either the patient or GES components. However, because of the large, unpredictable electrical charges involved in a lightning strike, disconnect the patient and discontinue the data acquisition session during a thunderstorm.

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## 1.4.7 Other Devices, System Accessories, and Peripherals



### WARNING:

- **Evaluate leakage risk.** If the GES is used in conjunction with electric stimulation devices, ask qualified personnel to evaluate any possible risk resulting from the sum of the leakage currents or connections within the GES, in compliance with IEC 60601-1.
- **GESs are not protected from defibrillation potentials.** Do not use GES components simultaneously with a defibrillator. If you must use a defibrillator, disconnect the HC GSN from the amplifier and move the amplifier away from the patient.
- **Certify all accessory equipment according to the relevant IEC standards.** Accessory equipment connected to the digital or clock sync ports of the amplifier must be certified according to the respective IEC standards (e.g., IEC 60950 for data processing equipment and IEC 60601-1 for medical equipment). Furthermore, all configurations shall comply with the system standard IEC 60601-1-1. Any person who connects additional equipment to the signal input port or signal output port configures a medical system, and is therefore responsible for ensuring that the system complies with the requirements of the system standard IEC 60601-1-1. If in doubt, consult EGI Technical Support (Table P-3).
- **Use only accessories, cables, and replacement parts sold by EGI.** The use of accessories and cables other than those that ship with the GES, with the exception of those sold by EGI as replacement parts for internal components, may result in increased emissions or decreased immunity of the GES.
- **Avoid stacking or adjoining EGI equipment with other equipment.** EGI equipment should not be used adjacent to or stacked with other equipment. If adjacent or stacked use is necessary, EGI equipment should be observed to verify normal operation in the configuration in which it will be used.

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## 1.4.8 Isolation Transformer



No maintenance instructions apply to isolation transformers other than fuse replacement. For fuse replacement instructions, refer to third-party manufacturer documentation.

## 1.4.9 Cleaning GES Components

To clean GES components (other than HC GSNs), do the following:

- Turn off and unplug GES components before cleaning.
- Prevent any liquid or sterilizing agent from entering any GES component.
- Do not use abrasive products.
- Clean the different surfaces, as follows:
  - *To clean cracks and near connectors:* Use a soft brush to remove dust.
  - *To clean camera lenses and monitor screens:* Use a lint-free, antiscratch brush or cloth.
  - *To clean external surfaces (except camera lenses and monitors screens):* Use a cloth dampened with mild soapy water or isopropyl alcohol, taking care not to wet any electrical contacts.
- Dry with a clean, dry, lint-free cloth.

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## 1.4.10 Component Recycling and Disposal



**WARNING:** Hazardous Material Disposal—

Replace internal batteries only with exactly matching batteries, which are available from EGI. For replacement and disposal instructions, contact EGI Technical Support (Table P-3).



**CAUTION:** Comply with local regulations when recycling or disposing of GES components, consumables, and accessories.

You may return components to EGI for recycling or disposal, if desired. Contact EGI Technical Support (Table P-3) to arrange for this service.

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## 2. FICS

The Field Isolation Containment System (FICS) enclosure houses the Net Amps amplifier and features shielding and input filtering that significantly reduce the effect of noise sources within the MR environment.

### 2.1 Overview and Specifications

**Table 2-1.** Dimensions and weight of the FICS

<b>Height</b>	19.1 cm (7.5 in.)	<b>Depth</b>	45.7 cm (18 in.)
<b>Width</b>	31.8 cm (12.5 in.)	<b>Weight</b>	13.6 kg (30 lb) [incl. amplifier]

**Table 2-2.** System requirements for the FICS's I/O ports

<b>Front panel Net port</b>	Standard Hypertronics 256- or 128-channel connector
<b>Rear panel DC power port</b>	15 VDC external power supply
<b>Bidirectional data/control port</b>	Proprietary fiber optic @ 368 Mb/sec
<b>Clock/sync port</b>	Proprietary fiber optic @ 368 Mb/sec

**Table 2-3.** RF/electromagnetic shielding of the FICS

<b>External RF fields between 100 to 450 MHz</b>	at least 90 dB attenuation
<b>RF/electromagnetic noise interference coupled onto the MR Net and through the Net cable into the amplifier</b>	at least 90 dB attenuation

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## 2.1.1 Battery Power

Within the MR environment, the FICS operates on battery power and can operate on battery power for up to eight (8) hours on a single charge.

Recharge the FICS's battery after use or after six months of nonuse.

The FICS's battery can be fully recharged within 12 to 14 hours.



**WARNING: Use special caution with lithium-ion polymer (LiPo) batteries—they may explode or burn if mishandled.**

LiPo batteries are volatile and burn hotter than ordinary batteries; therefore, they CANNOT be handled or charged casually as other batteries can be. **Failure to comply with these precautions may result in physical injury, death, or equipment damage.** For all questions and assistance, contact EGI Technical Support (Table P-3).

- Before charging, using, or shipping, *inspect LiPo batteries for damage*, such as swelling, punctured protective cover, or broken wiring or plug.
- NEVER charge, use, or ship any damaged LiPo battery.
- NEVER leave charging LiPo batteries unattended.
- ALWAYS charge LiPo batteries:
  - on a fireproof surface
  - away from combustibles
  - in a ventilated area
  - with an ABC fire extinguisher present
  - with correct polarity connection ensured
- NEVER modify LiPo batteries or LiPo battery chargers.
- NEVER use non-EGI LiPo batteries or non-EGI chargers.
- ALWAYS store LiPo batteries in fireproof containers.
- NEVER store LiPo batteries near other batteries, including other LiPos.



**WARNING: Hazardous Material Disposal—When needed, replace the FICS's internal lithium-ion polymer (LiPo) battery pack only with an exactly matching battery pack,** which is available from EGI. For replacement battery packs and disposal instructions, contact EGI Technical Support (Table P-3).

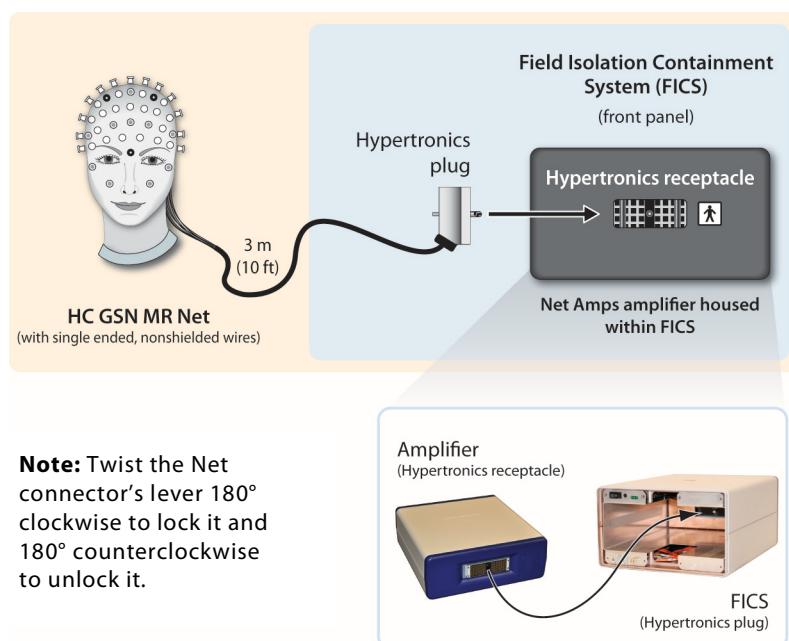
## 2.1.2 DC Power

DC power is only to be used when operating the FICS **outside of the MR environment for EEG-only acquisition**. When using the FICS outside of the MR environment, the amplifier can remain inside the FICS or be removed. When using the amplifier within the FICS, use the GES External Power Supply to power the amplifier. When using the amplifier outside of the FICS, refer to the GES 400 series manual (8100400).

## 2.2 Physical Connections

### 2.2.1 Front Connections

The longer cable of the MR Nets connects directly to the FICS. The Net Amps amplifier is housed within the FICS.



**Figure 2-1.** Hypertronics connections between the MR Net, FICS, and amplifier

## 2.2.2 Rear Connections

The FICS connects to other system components with the connections and indicators shown in Figure 2-2 and described in Table 2-4.



**Figure 2-2.** FICS rear panel connections and indicators

**Table 2-4.** FICS rear panel connections and indicators

Callout	Connection/ Indicator	Description
<b>A</b>	<b>Power ON/OFF</b>	Turns power on and off, whether the power is from the FICS's internal battery (required inside the MR imaging room) or the GES External Power Supply (allowed outside of the MR imaging room).
<b>B</b>	<b>Power Port</b>	<b>NOT TO BE USED INSIDE THE MR ENVIRONMENT.</b> Powers the FICS from the GES External Power Supply to recharge the FICS's internal battery or to power the amplifier for EEG-only acquisition outside of the MR environment.

---

Callout	Connection/ Indicator	Description
<b>C</b>	<b>Power LEDs</b> Indicate the status of the FICS's powered state.	 <b>CAUTION:</b> To fully recharge the FICS's internal battery and have a full eight (8) hours of power for your next recording session(s), do not interrupt the recharging process before it has completed. <b>Note:</b> You can collect data with a partially recharged battery, but you will not know how much time you have remaining when the power is reading low. <b>ON/LOW</b> (left). When illuminated, the FICS's internal battery is fully powered. When flashing, battery power is low. <b>CHARGE</b> (center). When illuminated, the FICS's internal battery is being charged. When extinguished, the battery is fully charged. <b>BALANCE</b> (right). When illuminated, the charger is balancing the charges of the three battery cells during recharging.
<b>D</b>	<b>Data I/O</b> For research only	Brings digital I/O events into the amplifier via the Net Amps clock sync.  <b>WARNING:</b> See all warnings in the "Safety and Use Conditions" chapter before connecting accessory equipment.  Refer to third-party manufacturer documentation.
<b>E</b>	<b>AUX</b>	Not used.
<b>F</b>	<b>Clock Sync</b>	Brings synchronized timing from the MR control rack into the EEG amplifier via the Net Amps clock sync. This synchronized timing facilitates the attenuation of predictable MR artifacts.

---

## 2.3 Removing/Inserting the Amplifier



**CAUTION:** When shipping the FICS and/or the Net Amps amplifier, ship them separately within their original protective cases. Never ship the FICS with the amplifier inside it.

To remove the Net Amps amplifier from the FICS, do the following.

**Note:** To reinstall the amplifier, reverse the steps.

- ① Disconnect the GES External Power Supply, if connected.

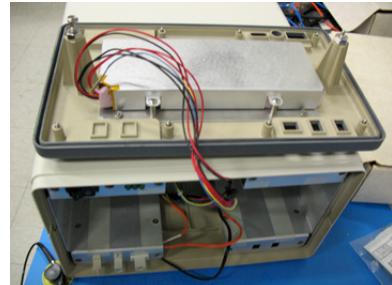


- ② Remove the eight screws from the FICS's rear panel.



**CAUTION:** While handling the FICS's rear panel, do not damage the RF shielding metal strip that is attached to the FICS's rear panel. Damage will reduce EEG signal quality. If damaged, contact EGI Technical Support (Table P-3) for replacement.

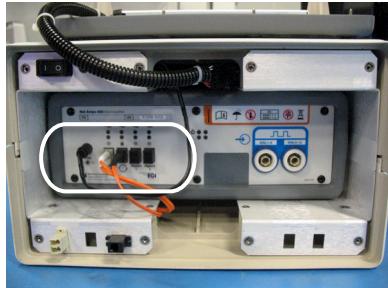
- ③ Carefully detach the rear panel, pull it straight out, then move it only a few inches to set it atop or aside of the chassis. Do not damage the RF shielding or pull the battery pack cables.



- 
- ④ Optional:** If desired, you may disconnect the battery pack's 6-wire and 2-wire cables located near the undercarriage.

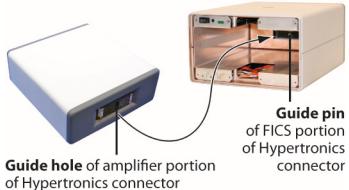


- ⑤** Detach all cables (power, data, and clock sync) between the FICS and the amplifier.

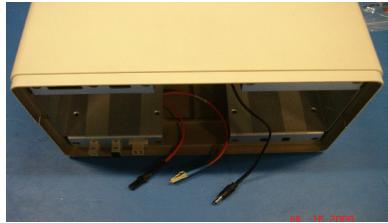


- ⑥** To properly disconnect the Hypertronics connector between the FICS and amplifier, firmly grasp the amplifier and pull it straight out from the FICS.

**Note:** When reinstalling, carefully align the guide pin and hole of the connector.



- 
- 7 Tuck all FICS cables (power, data, and clock sync) into the undercarriage cable area.



- 8 While ensuring that you do not damage the RF shielding metal strip, carefully reattach the FICS's rear panel.



- 9 Reinstall the rear panel's eight screws. Tighten until snug, but not overtight.



---

# 3. Net Amps Amplifiers

The current models of the Net Amps amplifier are dual purpose—they can be used inside the MR environment for EEG-fMRI acquisition as well as outside of the MR environment for EEG-only acquisition.



**WARNING:** The Net Amps amplifier is never to be used as a standalone device **inside** the MR environment.

Inside the MR environment, the Net Amps amplifier **must be** housed within the Field Isolation Containment System (FICS) and **must be** powered by the FICS's internal battery.

For all safety and use conditions for using the Net Amps amplifiers *outside* of the MR environment, refer to the GES 400 series manual (8100400).

Each channel of the Net Amps amplifier continuously detects the voltage being acquired at the corresponding sensor of the HydroCel Geodesic Sensor Net MR (HC GSN MR). This voltage is amplified, filtered, sampled, and digitized.

## 3.1 Overview and Specifications

**Table 3-1.** Dimensions and weight of the Net Amps amplifier

<b>Height</b>	10.77 cm (4.24 in.)	<b>Depth</b>	30.18 cm (11.88 in.)
<b>Width</b>	28.98 cm (11.41 in.)	<b>Weight</b>	6.8 kg (15 lb)

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**Table 3-2.** Performance specifications of the Net Amps amplifier within the MR environment

<b>Sampling frequencies</b>	Sampling rates (per model): <ul style="list-style-type: none"><li>• Up to 8 Ksps for the NA 400</li><li>• Up to 20 Ksps for the NA 410</li></ul>
<b>Conversion</b>	24-bit A/D
<b>Noise</b>	0.7 $\mu$ V RMS (1.4 $\mu$ V pp)
<b>Dynamic range</b>	$\pm$ 200 mV
<b>Precision</b>	0.024 $\mu$ V/bit
<b>Common-mode rejection</b>	$\geq$ 90 dB
<b>Isolation-mode rejection</b>	$\geq$ 120 dB
<b>Filters</b>	4 KHz antialiasing filter
<b>Input impedance</b>	$\geq$ 1.0 G $\Omega$
<b>Patient isolation</b>	4 kV

## 3.2 Anti-aliasing Filter Effects on EEG Timing

The anti-aliasing filters of the Net Amps amplifiers introduce a temporal delay in the EEG. Whether EEG is steaming, displaying, or recording, there is a temporal delay from *real time* and any event aligned with real time.

Without adjustment, this delay affects the alignment of EEG with the real-time events (as from digital inputs or TCP/IP connection) recorded during EEG acquisition.

This delay does not affect the alignment of events manually entered during EEG acquisition. It also does not affect the alignment of events entered during review or from the operation of tools after data acquisition.

**Note:** Net Station 5.1.1 and later provide options for automatic adjustment of this delay.

---

If you are segmenting data, you can adjust the delay between EEG and real-time events by adding a positive value in the Offset Segment field of the Segmentation tool, in addition to adjusting for external event or digital input (DIN) offsets. For details, refer to the Net Station 5 manual (8100050) or contact EGI Technical Support (Table P-3).



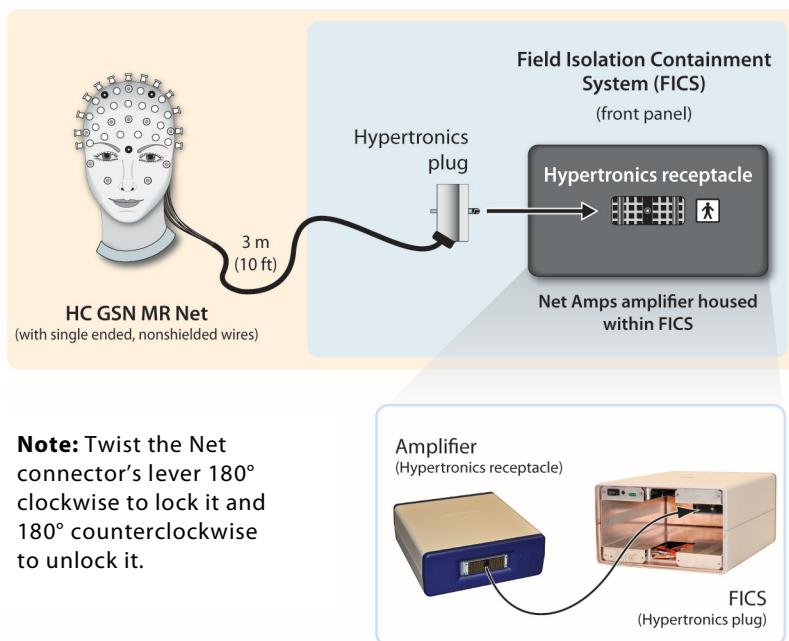
**CAUTION:** The anti-aliasing filters of the Net Amps amplifiers introduce a temporal delay in the EEG. To adjust for the delay between recorded EEG and the real-time events recorded during EEG acquisition, use the following known delays for each sampling rate and amplifier model:

<b>Sampling Rate</b>	<b>NA 300</b>	<b>NA 400</b>	<b>NA 405</b>	<b>NA 410</b>
1,000 s/s	8 ms	36 ms	36 ms	13 ms
500 s/s	18 ms	66 ms	66 ms	34 ms
250 s/s	36 ms	112 ms	112 ms	76 ms
125 s/s	72 ms			

## 3.3 Physical Connections

### 3.3.1 Front Connections

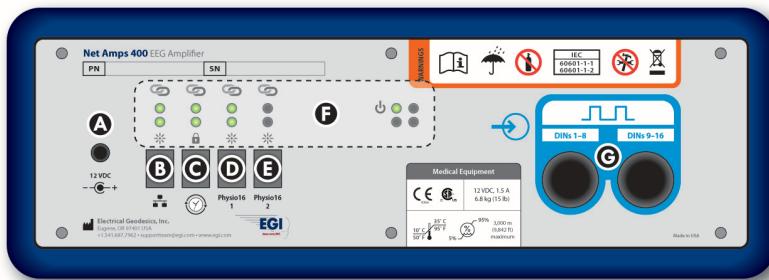
The longer cable of the MR Nets connects directly to the FICS. The Net Amps amplifier is housed within the FICS.



**Figure 3-1.** Hypertronics connections between the MR Net, FICS, and amplifier

### 3.3.2 Rear Connections

**When used as a standalone device**, the Net Amps amplifier connects to other system components with the connections and indicators shown in Figure 3-2 and described in Table 3-3.



**Figure 3-2.** Net Amps amplifier rear panel connections and indicators

**Table 3-3.** Net Amps amplifier rear panel connections and indicators

Callout	Connection/ Indicator	Description
A	<b>Power</b>	Power cable connects to the isolation transformer through the GES External Power Supply.
B	<b>Ethernet</b>	Fiber optic cable connects to an Ethernet switch, which then connects to the DAC (via CAT5 cable) for Ethernet bidirectional communication.
C	<b>Clock Sync</b>	Fiber optic cable connects to the Net Amps clock sync device to synchronize the clock of other manufacturer's equipment with the amplifier.
D	<b>Physio16 (1)</b>	Fiber optic cable connects to one optional Physio16 for PNS measures.
E	<b>Physio16 (2)</b>	Fiber optic cable connects to a second optional Physio16 for additional PNS measures.

---

Callout	Connection/ Indicator	Description		
<b>F</b>	<b>LEDs</b> Connection indicators	<b>Linked</b>		When illuminated, communication between devices is linked.
		<b>Active</b>		When illuminated, the connection between devices is active.
		<b>Locked</b>		When illuminated, the connection between devices is locked.
	<b>LEDs</b> Status indicators	<b>Power</b>		When illuminated, the amplifier is powered, turned on, and ready to collect data.
		<b>blanks</b>		For manufacturer's use only.
<b>G</b>	<b>Digital</b> For research only	When used, provides digital inputs from ancillary equipment, such as stimulus control devices, for monitoring and recording the occurrence and duration of external trigger signals, along with the EEG.		<b>WARNING:</b> See all warnings in the "Safety and Use Conditions" chapter before connecting accessory equipment.
				Refer to third-party manufacturer documentation.

---

# 4. Other GES Components

## 4.1 HydroCel GSN MRs

EGI's MR-conditional HydroCel Geodesic Sensor Net MRs (HydroCel GSN MR Nets) provide you with:

- specially designed electrodes that incorporate specific absorption rate (SAR) mitigation,
- two ECG channels to facilitate ballistocardiogram attenuation,
- longer cables to allow the Nets to go into a magnet,
- easy application with saline solution,
- usability outside of the MR environment for routine EEG-only acquisition, and
- a full range of channel counts (32 to 256).

See Figure 2-1 for how HC GSN MR Nets connect to the FICS.

For the step-by-step instructions for applying your HC GSN MR Nets, refer to the EEG-fMRI preparation instructions (8402100).

## 4.2 Net Amps Clock Sync

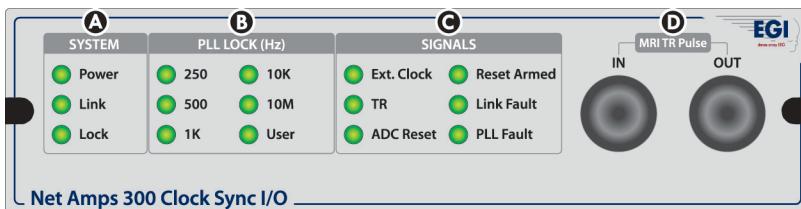
The Net Amps clock sync device synchronizes the timing between two different systems (EEG and fMRI, MEG, etc.) for simultaneous recording. When used to synchronize the MR magnet and the EEG amplifier to an external clock source, it uses the MRI gradient pulses to synchronize the data acquisition.



**CAUTION:** The Net Amps clock sync is **MR UNSAFE** and **not to be positioned or used within the MR environment**. To use the Net Amps clock sync, position it outside the MR environment and extend its fiber optic cable into the MR environment.

### 4.2.1 Front Panel Connections and Indicators

The Net Amps clock sync connects to other system components with the connections and indicators shown in Figure 4-1 and described in Table 4-1.



**Figure 4-1.** Net Amps clock sync front panel connections and indicators

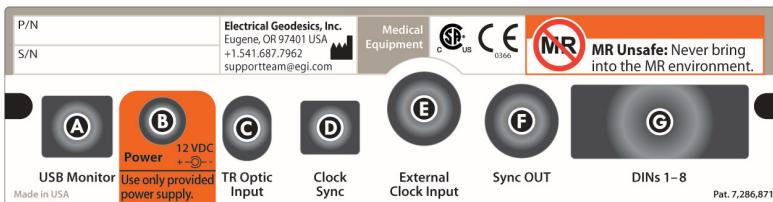
**Table 4-1.** Net Amps clock sync front panel connections and indicators

Callout	Connection/ Indicator	Description
<b>A</b>	<b>System LEDs</b>	<p>Indicate the system's status.</p> <p><b>Power</b> (top). When illuminated, the Net Amps clock sync is powered.</p> <p><b>Link</b> (middle). When illuminated, the amplifier and clock sync are connected, working, and communicating with each other.</p> <p><b>Lock</b> (bottom). When illuminated, the PLL (phase lock loop) of the amplifier is locked to the MR clock of the MRI scanner. Locking occurs about one minute after the clock sync is powered.</p>
<b>B</b>	<b>PLL Lock (Hz) LEDs</b>	<p>Indicate which clock frequency the PLL is locked to. The default frequency is 10 MHz. One frequency is available for custom applications.</p>
<b>C</b>	<b>Signals LEDs</b>	<p>Indicate whether or not the various system signals have been detected.</p> <p><b>Ext. Clock</b> (top left). When illuminated, the external MR clock input is detected and active.</p> <p><b>TR</b> (middle left). When illuminated, the clock sync detects the MR system's TR pulse. Detection occurs about two seconds after the MRI scanner begins scanning (and pulses once for each head volume scanned thereafter).</p> <p><b>ADC Reset</b> (bottom left). <i>Works in conjunction with the Reset Armed LED—this LED responds <b>second</b>.</i> The ADC Reset process is used to ensure that the TR pulse is not sampled when it is changing. <u>Specifically</u>, after the ADC Reset process is initiated and the first TR pulse is detected, this LED illuminates and the ADC (analog-to-digital converter) is reset to align with the TR pulse (plus a 10 microsecond delay). This LED extinguishes when the process is complete.</p> <p><b>Reset Armed</b> (top right). <i>Works in conjunction with the ADC Reset LED—this LED responds <b>first</b>.</i> The Reset Armed process is used to ensure that the ADC Reset process occurs only once per MRI scan. <u>Specifically</u>, if no TR pulse is detected for the first 30 seconds of an MRI scan, then this LED illuminates and the ADC Reset process is</p>

Callout	Connection/ Indicator	Description
		<p>initiated to wait for the first TR pulse. When the first TR pulse occurs, this LED extinguishes.</p> <p><b>Link Fault</b> (middle right). When illuminated, a problem has been detected with the fiber optic connection between the clock sync and the amplifier.</p> <p><b>PLL Fault</b> (bottom right). When illuminated, the PLL cannot lock to the external sync input signal.</p>
<b>D</b>	<b>MRI TR Pulse ports</b>	<p>Provide a gateway for synchronized TR pulse inputs and outputs between the MR control rack and other devices in the system.</p> <p><b>In</b> (left). One of two connections on the clock sync device that accepts a TR pulse input from the TR port on the MR control rack—this one via coaxial BNC cable. The fiber optic (TR Optic Input) port is on the rear panel of clock sync device.</p> <p><b>Out</b> (right). Provides a coaxial BNC cable TR pulse output to such devices as a response pad console.</p>

#### 4.2.2 Rear Panel Connections and Indicators

The Net Amps clock sync connects to other system components with the connections shown in Figure 4-2 and described in Table 4-2.



**Figure 4-2.** Net Amps clock sync rear panel connections

**Table 4-2.** Net Amps clock sync rear panel connections

Callout	Connection/ Indicator	Description
<b>A</b>	<b>USB Monitor</b>	For manufacturer's use only.
<b>B</b>	<b>12 VDC Power</b>	Connects to the provided power supply.
<b>C</b>	<b>TR Optic Input</b>	One of two connections on the clock sync device that accepts a TR pulse input from the TR port on the MR control rack—this one via fiber optic cable. The coaxial BNC (MRI TR Pulse IN) port is on the front panel of clock sync device.
<b>D</b>	<b>Clock Sync</b>	Transmits both the MR clock and TR timing pulses from the MR control rack to the EEG amplifier via fiber optic cable through the FICS's Clock Sync port. This synchronized timing facilitates the attenuation of predictable MR artifacts.
<b>E</b>	<b>External Clock Input</b>	Connects to the clock source of another manufacturer's equipment to synchronize the timing of the EEG amplifier to that system.
<b>F</b>	<b>Sync OUT</b>	Provides a clock source to another manufacturer's equipment for the synchronization of timing for non-NTP setups.
<b>G</b>	<b>DINs 1–8</b>  For research only	<p>When recording EEG-fMRI, you must use this digital I/O port (not the ports on the amplifier) to provide digital inputs from ancillary equipment, such as stimulus control devices. This port provides eight channels of digital inputs for monitoring and recording the occurrence and duration of external trigger signals, along with the EEG, within Net Station.</p> <p> <b>WARNING:</b> See all warnings in the "Safety and Use Conditions" chapter before connecting accessory equipment.</p> <p> Refer to third-party manufacturer documentation.</p>

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## 4.3 Net Station and DAC

The Net Station EEG software resides on a GES-compatible data acquisition computer (DAC). The Net Amps amplifier sends packets of data containing digitized EEG samples to the DAC so that the Net Station EEG software can acquire, display, review, store, and evaluate them. Your system may have one or more laptop or desktop DACs that are compatible with the amplifier(s) of your GES system.



**CAUTION:** Before upgrading your EGI system (computer, operating system, or EGI software), confirm compatibility with EGI Technical Support (Table P-3).



For computer specifications and operation instructions, refer to third-party manufacturer documentation.

**For details about the Net Station software, refer to the Net Station manual (8100050).**

## 4.4 Ethernet Switch

All EGI systems include an Ethernet switch that links the system's Ethernet devices (such as the Net Amps amplifier and the DAC).



**CAUTION:** If needed, replace the Ethernet switch only with an exactly matching replacement, or contact EGI Technical Support (Table P-3) for an equivalent substitute.

## 4.5 GES External Power Supply



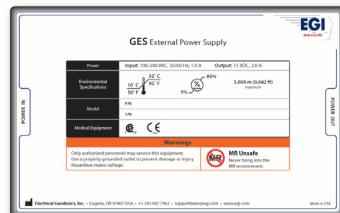
### CAUTION:

- The medical grade GES External Power Supply is **MR UNSAFE** and **not to be connected or used within the MR environment**. While inside the MR imaging room, power the FICS by its internal battery.
- DO NOT unplug the GES External Power Supply from the FICS while the internal battery is being recharged.

**NOT TO BE USED INSIDE THE MR ENVIRONMENT.**

***Used only outside of the MR environment to:***

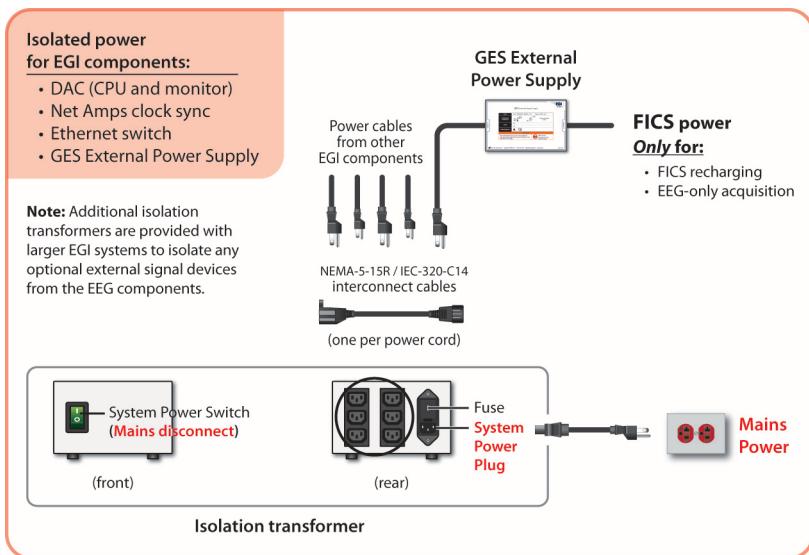
- recharge the FICS's internal battery
- power the amplifier for EEG-only acquisition



## 4.6 Isolation Transformer

All EGI systems include one or more isolation transformers (medical grade Toroid W Series), and all EGI components, **except the FICS**, must plug into an isolation transformer to provide the attached components with isolation from mains power for patient safety.

**Note:** If more than one isolation transformer is included, it is used to isolate any optional event related potential (ERP) components (for research only) from the EEG components.



**WARNING:** For all system equipment warnings, cautions, and conditions for use, refer to the "Safety and Use Conditions" chapter of this manual.

**Figure 4-3.** Isolation transformer connections for GES MRs

**Table 4-3.** General specifications for the Toroid W Series isolation transformers

<b>Compliance</b>	UL2601.1, CSA C22.2 No. 601.1, EN60601-1, EN60742, IEC601-1, CE Mark
<b>Power</b>	Selectable, 115 or 230 V 50-60 Hz, input/output
<b>Leakage current</b>	< 100 µA
<b>Outlets</b>	Appliance type (IEC 60320)
<b>Miscellaneous</b>	Low weight, low magnetic strayfield, low mechanical noise, low losses, and high efficiency

**Table 4-4.** ISB-030M specifications and peak power values within laptop GES MRs

<b>Fuse rating</b>	3.15 AT (120 V in.) or 1.6 AT (240 V in.)
<b>Capacity</b>	300 VA max.
<b>Amplifier power dissipation</b>	15 VA
<b>DAC and amplifier load</b>	55 VA

---

**Table 4-5.** ISB-060M specifications and peak power values within desktop GES MRs

<b>Fuse rating</b>	6.0 AT (120 V in.) or 3.15 AT (240 V in.)
<b>Capacity</b>	600 VA max.
<b>Amplifier power dissipation</b>	15 VA
<b>DAC, monitor, and amplifier load</b>	245 VA



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# 5. System Configurations

All connections that are required for the operation of your EGI system are made by an EGI support or authorized engineer during installation. After the EGI support or authorized engineer has installed and trained you on the use of your EGI system, including the Net Station software, it is ready to use with minimum preparation.

This chapter illustrates the typical GES MR system configurations for:

- EEG-fMRI data (see 5.1)
- EEG-fMRI data with ERP (see 5.2)

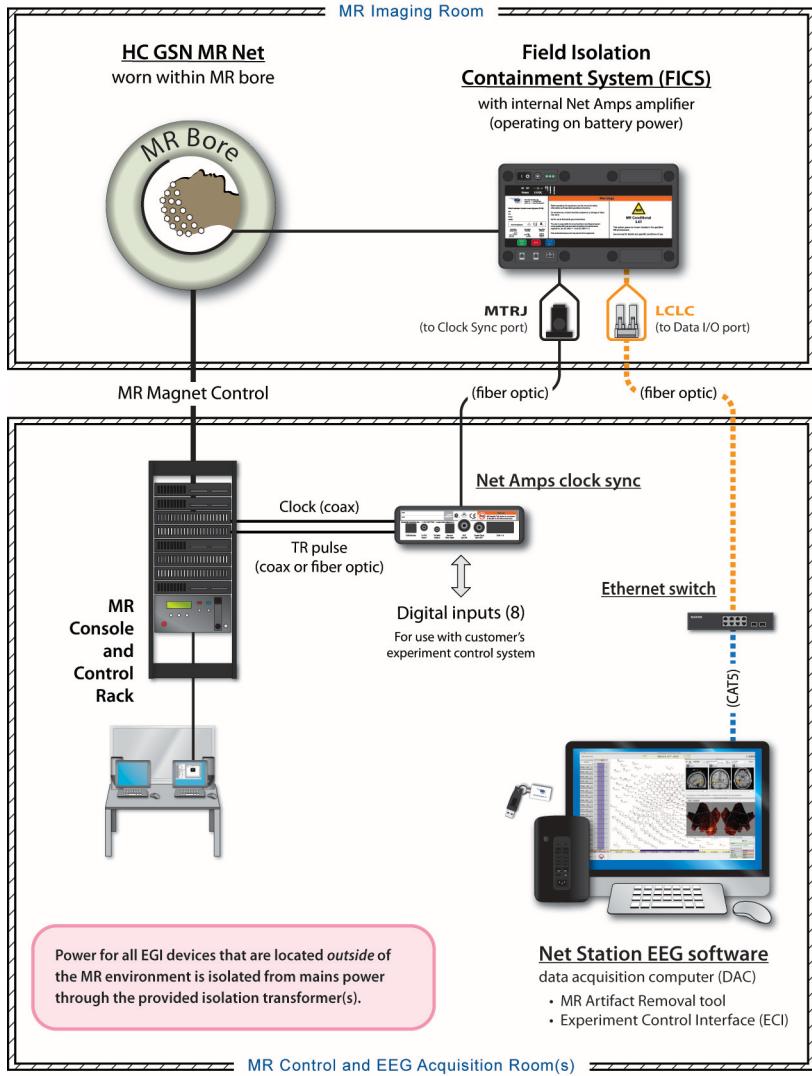
For the step-by-step instructions for using the various components of your EGI system, refer to the manuals and instructions that shipped with your GES MR system configuration.



For the use instructions of experiment control devices, refer to third-party manufacturer documentation.

For additional questions, contact EGI Technical Support (Table P-3).

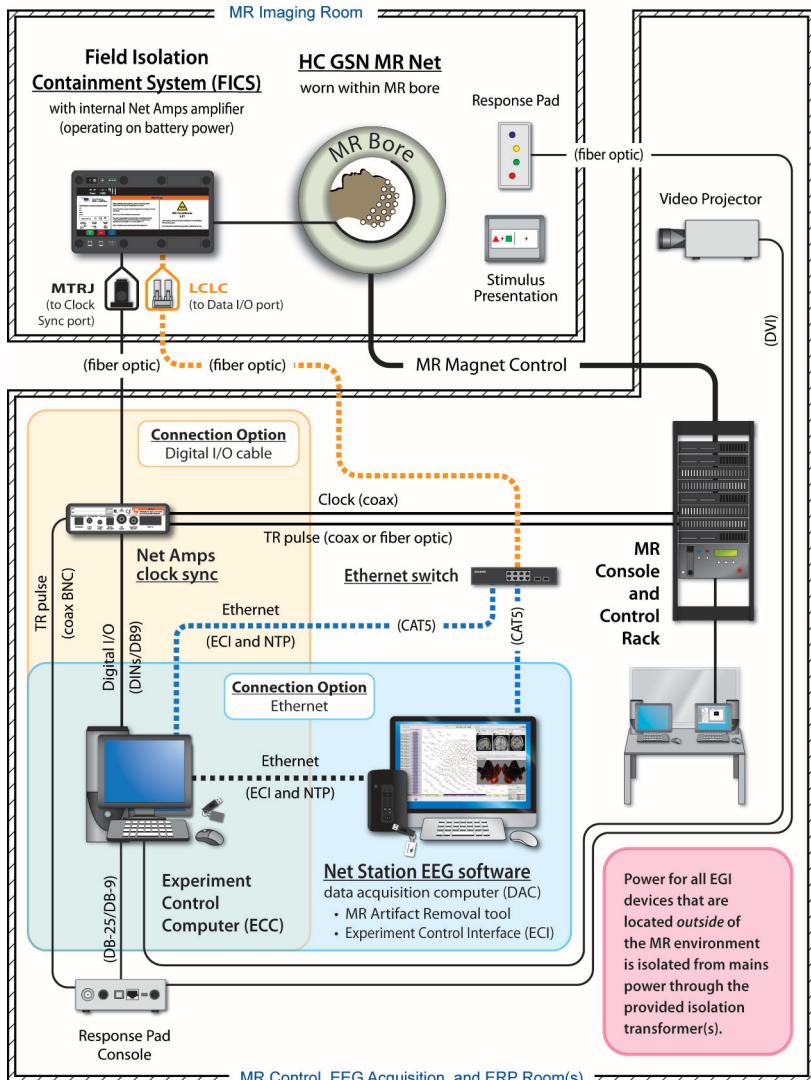
## 5.1 EEG-fMRI



**WARNING:** For all EGI system equipment warnings, cautions, and conditions for use, refer to the "Safety and Use Conditions" chapter of this manual.

**Figure 5-1.** Typical EEG-fMRI configuration

## 5.2 EEG-fMRI with ERP



**Figure 5-2.** Typical EEG-fMRI with ERP configuration



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# Appendix A: EMC Declarations

Geodesic EEG Systems (GESs) must be installed and put into service according to the electromagnetic compliance (EMC) guidelines and declarations provided here.

- Electromagnetic emissions (see Table A-1)
- Electromagnetic immunity (see Table A-2)
- Electromagnetic immunity for non-life-supporting equipment, such as GES components (see Table A-3)
- Recommended separation distances between radio-frequency (RF) communications equipment and the GES (see Table A-4)

**Note:** Portable and mobile RF communications equipment can affect GESs.



**WARNING:** The use of accessories and cables other than those sold by EGI may result in increased emissions or decreased immunity of the GES.



**WARNING:** EGI equipment should not be used adjacent to or stacked with other equipment. If adjacent or stacked use is necessary, the EGI equipment should be observed to verify normal operation in the configuration in which it will be used.

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# Electromagnetic Emissions

**Table A-1.** Electromagnetic compatibility (EMC) emissions guidelines and declarations for GESs

GESs are intended for use in the electromagnetic environment specified below. The customer or user of a GES should ensure that it is used in such an environment.		
Emissions Test	Compliance	Electromagnetic Environment—Guidance
RF emissions CISPR 11	Group 1	The GES uses RF energy only for its internal functions. Therefore, its RF emissions are very low and are not likely to cause any interference in nearby electronic equipment.
RF emissions CISPR 11	Class A	The GES is suitable for use in all establishments other than domestic and those directly connected to the public low-voltage power-supply network that supplies buildings used for domestic purposes.
Harmonic emissions IEC 61000-3-2	Class A	
Voltage fluctuations/flicker emissions IEC 61000-3-3	Complies	

# Electromagnetic Immunity

**Table A-2.** Electromagnetic compatibility (EMC) immunity guidelines and declarations for GESs

GESs are intended for use in the electromagnetic environment specified below. The customer or user of a GES should ensure that it is used in such an environment.			
Immunity Test	IEC 60601 Test Level	Compliance Level	Electromagnetic Environment—Guidance
Electrostatic discharge (ESD) IEC 61000-4-2	± 6 kV contact ± 8 kV air	± 6 kV contact ± 8 kV air	Floors should be wood, concrete, or ceramic tile. If floors are covered with synthetic material, the relative humidity should be at least 30%.
Electrical fast transient/burst IEC 61000-4-4	± 2 kV for power-supply lines ± 1 kV for input/output lines	± 2 kV for power-supply lines ± 1 kV for input/output lines	Mains power quality should be that of a typical commercial or hospital environment.
Surge IEC 61000-4-5	± 1 kV differential mode ± 2 kV common mode	± 1 kV differential mode ± 2 kV common mode	Mains power quality should be that of a typical commercial or hospital environment.

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<b>Immunity Test</b>	<b>IEC 60601 Test Level</b>	<b>Compliance Level</b>	<b>Electromagnetic Environment—Guidance</b>
Voltage dips, short interruptions, and voltage variations on power-supply input lines IEC 61000-4-11	< 5% $U_T$ (> 95% dip in $U_T$ ) for 0.5 cycle  40% $U_T$ (60% dip in $U_T$ ) for 5 cycles  70% $U_T$ (30% dip in $U_T$ ) for 25 cycles  < 5% $U_T$ (> 95% dip in $U_T$ ) for 5 sec.	< 5% $U_T$ (> 95% dip in $U_T$ ) for 0.5 cycle  40% $U_T$ (60% dip in $U_T$ ) for 5 cycles  70% $U_T$ (30% dip in $U_T$ ) for 25 cycles  < 5% $U_T$ (> 95% dip in $U_T$ ) for 5 sec.	Mains power quality should be that of a typical commercial or hospital environment. If the user of the GES requires continued operation during power mains interruptions, it is recommended that the GES be powered from an uninterruptible power supply or a battery.
Power frequency (50/60 Hz) magnetic field IEC 61000-4-8	3 A/m	3 A/m	Power frequency magnetic fields should be at levels characteristic of a typical location in a typical commercial or hospital environment.

**Note:**  $U_T$  is the AC mains voltage before application of the test level.

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# Electromagnetic Immunity for Non-life-supporting Equipment

**Table A-3.** Electromagnetic compatibility (EMC) immunity guidelines and declarations for non-life-supporting equipment (such as GES components)

GESs are intended for use in the electromagnetic environment specified below. The customer or user of a GES should ensure that it is used in such an environment.

Immunity Test	IEC 60601 Test Level	Compliance Level	Electromagnetic Environment—Guidance
Conducted RF IEC 61000-4-6	3 V rms 150 kHz to 80 MHz	3 V rms	Portable and mobile RF communications equipment should be used no closer to any part of the GES, including cables, than the recommended separation distance calculated from the equation applicable to the frequency of the transmitter.  <b>Recommended separation:</b> $d = 1.2 \sqrt{P}$
Radiated RF IEC 61000-4-3	3 V/m 80 MHz to 2.5 GHz	3 V/m	$d = 1.2 \sqrt{P}$ 80 MHz to 800 MHz $d = 2.3 \sqrt{P}$ 800 MHz to 2.5 GHz  where P is the maximum output power rating of the transmitter in watts (W) according to the transmitter manufacturer, and d is the recommended separation distance in

Immunity Test	IEC 60601 Test Level	Compliance Level	Electromagnetic Environment—Guidance
			<p>meters (m). Field strengths from fixed RF transmitters, as determined by the electromagnetic site survey,<sup>a</sup> should be less than the compliance level in each frequency range.<sup>b</sup> Interference may occur in the vicinity of equipment marked with the following symbol:</p> 
<p><b>Note 1:</b> At 80 MHz and 800 MHz, the higher frequency range applies.</p> <p><b>Note 2:</b> These guidelines may not apply in all situations. Electromagnetic propagation is affected by absorption and reflection from structures, objects, and people.</p>			
<p><sup>a</sup> Field strengths from fixed transmitters, such as base stations for radio (cellular/cordless) telephones and land mobile radios, amateur radio, AM and FM radio broadcast, and TV broadcast cannot be predicted theoretically with accuracy. To assess the electromagnetic environment due to fixed RF transmitters, and electromagnetic site survey should be considered. If the measured field strength in the location in which the GES is used exceeds the applicable RF compliance level above, the GES should be observed to verify normal operation. If abnormal performance is observed, additional measures may be necessary, such as reorienting or relocation the GES.</p> <p><sup>b</sup> Over the frequency range 150 KHz to 80 MHz, field strengths should be less than 3 V/m.</p>			

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# Recommended Separation Distances Between Radio-frequency (RF) Communications Equipment

**Table A-4.** Recommended separation distances between RF communications equipment (portable and mobile) and GES components

Rated Maximum Output Power of Transmitter (in watts)	Separation Distance According to Frequency of Transmitter (in meters)		
	150 kHz to 80 MHz $d = 1.2 \sqrt{P}$	80 MHz to 800 MHz $d = 1.2 \sqrt{P}$	800 MHz to 2.5 GHz $d = 2.3 \sqrt{P}$
0.01	0.12	0.12	0.23
0.1	0.38	0.38	0.73
1	1.2	1.2	2.3
10	3.8	3.8	7.3
100	12	12	23
For transmitters rated at a maximum output power not listed above, the recommended separation distance $d$ in meters (m) can be estimated using the equation applicable to the frequency of the transmitter, where $P$ is the maximum output power rating of the transmitter in watts (W) according to the transmitter manufacturer.			
<b>Note 1:</b> At 80 MHz and 800 MHz, the separation distance for the higher frequency range applies.			
<b>Note 2:</b> These guidelines may not apply in all situations. Electromagnetic propagation is affected by absorption and reflection from structures, objects, and people.			







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