



## GNSS AND LOCATION TECHNOLOGIES FOR LOGGING SAFETY

Cooperative agreement 5 U01 OH010841

Rob Keefe, Ph.D.  
Associate Prof. of Forest Operations  
Director and Forest Manager  
University of Idaho Experimental Forest

# OUTLINE

- Introduction
- Safety benefits of location-sharing in forestry
  - Avoidance*
  - Detection*
  - Response*
- Perceptions of location-sharing
- Discussion





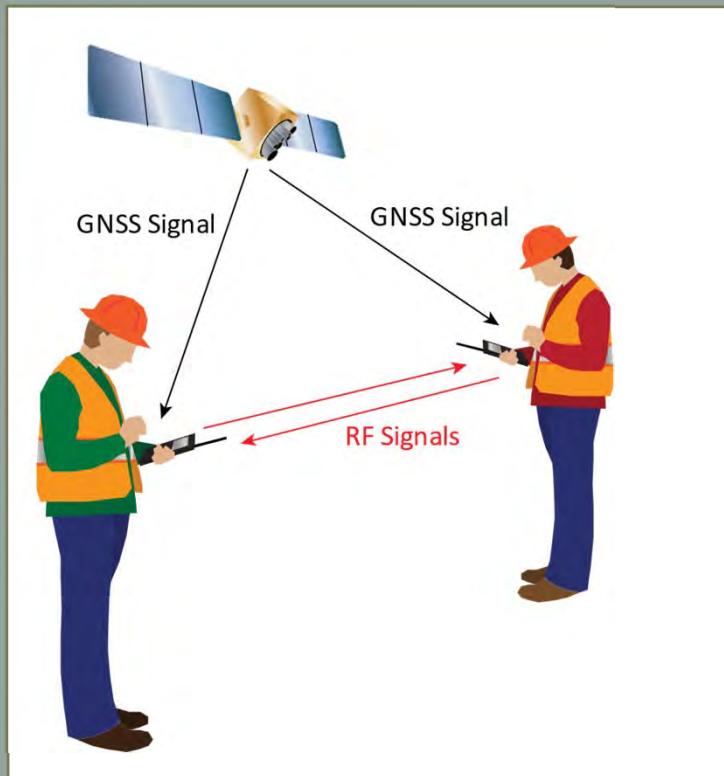




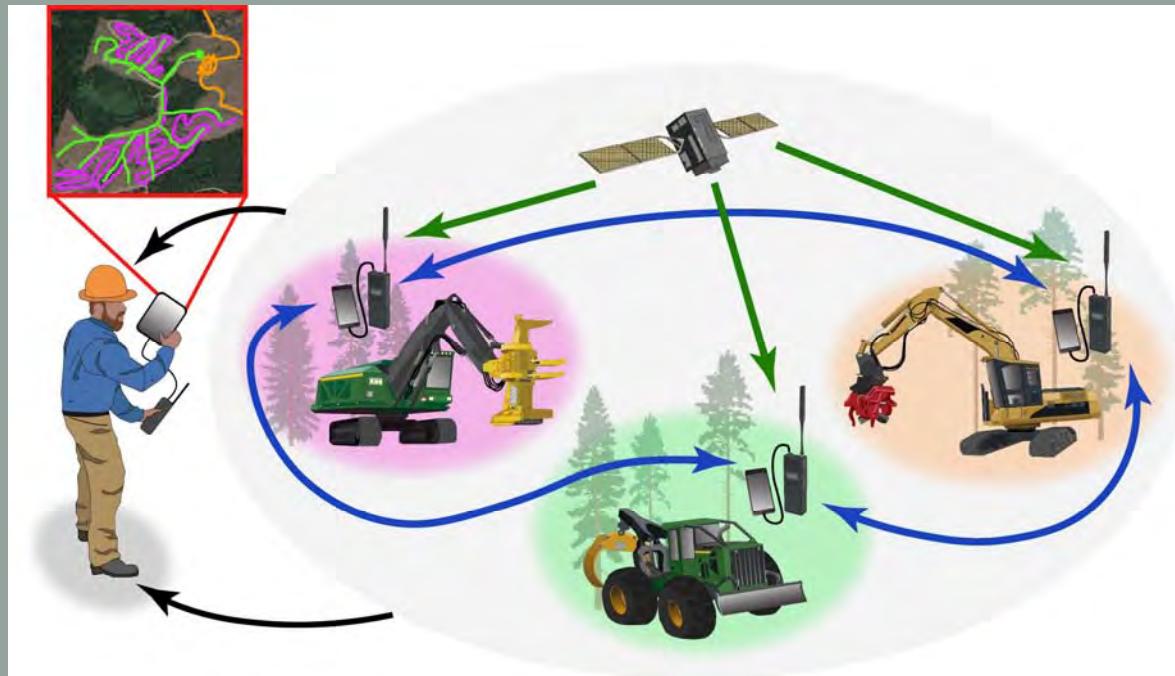




# INCREASING SITUATIONAL AWARENESS

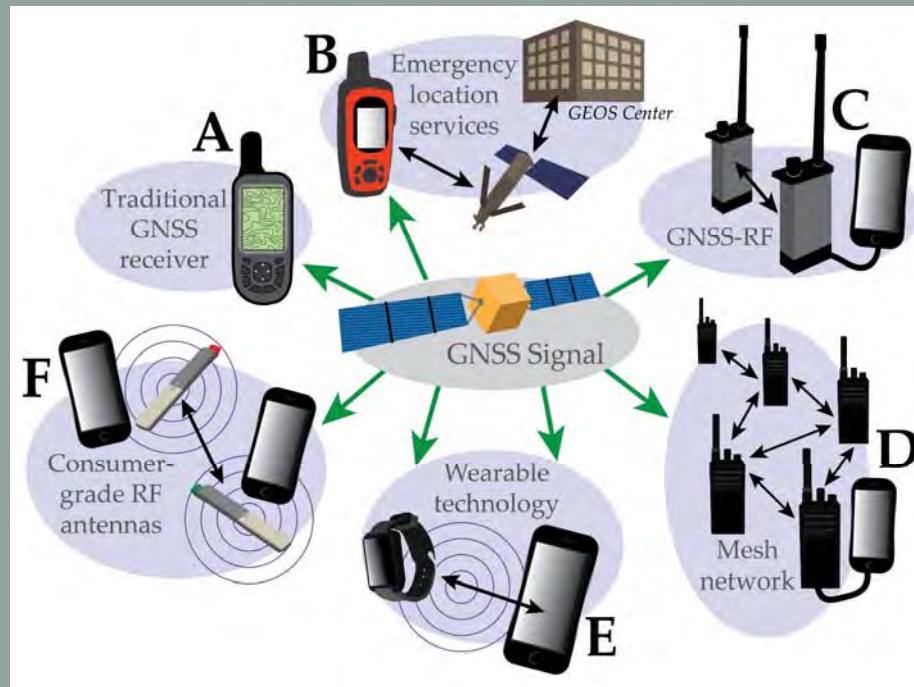


# INCREASING SITUATIONAL AWARENESS



Keefe, R.F., Wempe, A.M., Becker, R.M., Zimbelman, E.G., Nagler, E.G., Gilbert, S.M. and C. Caudill. Positioning methods and the use of location and activity data in forests. *Forests*

# LOCATION SHARING DEVICES

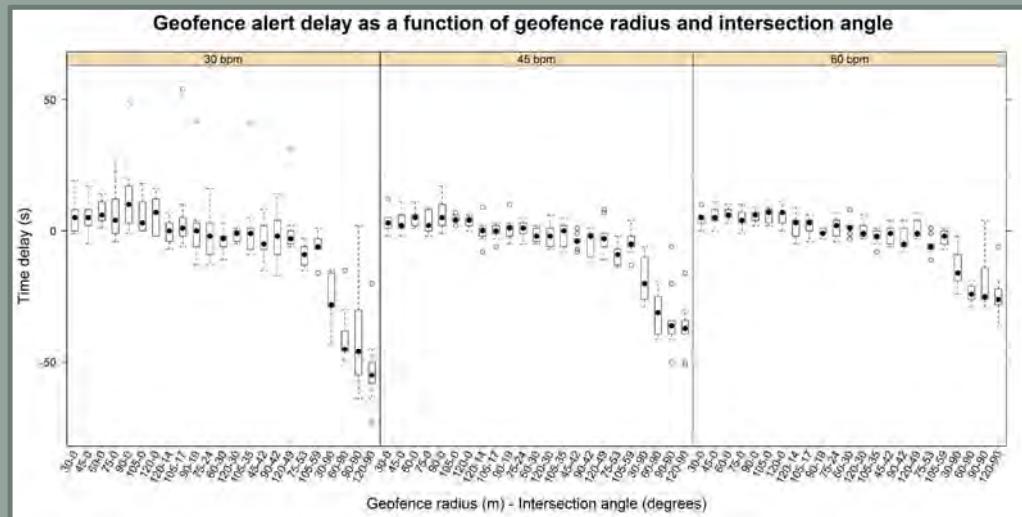
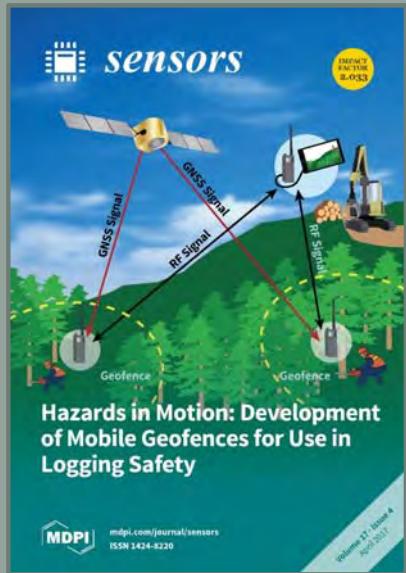


Keefe, R.F., Wempe, A.M., Becker, R.M., Zimbelman, E.G., Nagler, E.G., Gilbert, S.M. and C. Caudill. Positioning methods and the use of location and activity data in forests. *Forests*

# AVOIDANCE: GEOFENCES

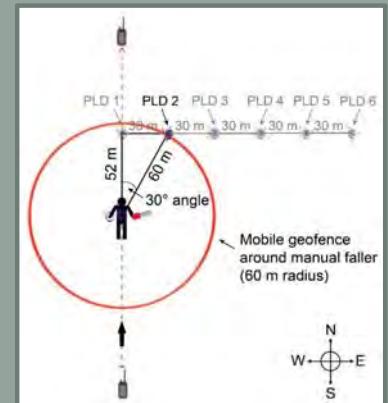


# AVOIDANCE: GEOFENCES



Article  
**Hazards in Motion: Development of Mobile Geofences for Use in Logging Safety**

Eloise G. Zimbelman \*, Robert F. Keefe, Eva K. Strand, Crystal A. Kolden and Ann M. Wempe



# AVOIDANCE: GEOFENCES



*Article*

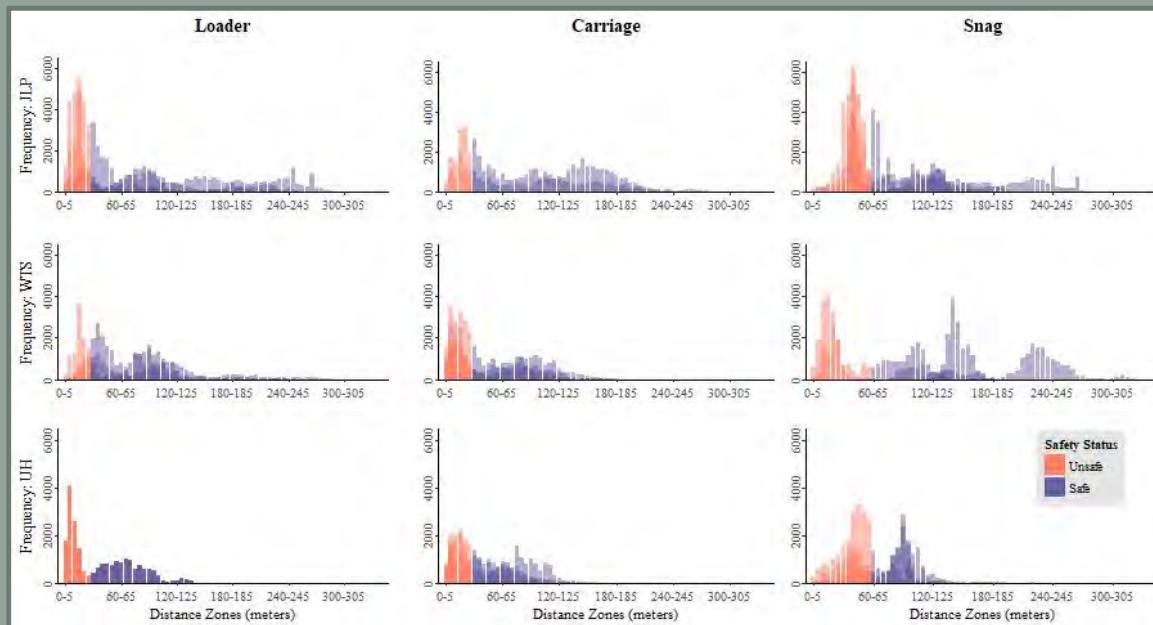
**Characterizing Rigging Crew Proximity to Hazards on Cable Logging Operations Using GNSS-RF: Effect of GNSS Positioning Error on Worker Safety Status**

Ann M. Wempe \* and Robert F. Keefe 

# AVOIDANCE: GEOFENCES



# AVOIDANCE: GEOFENCES

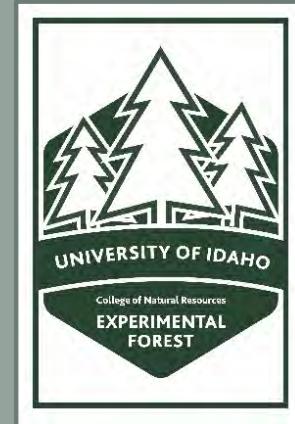
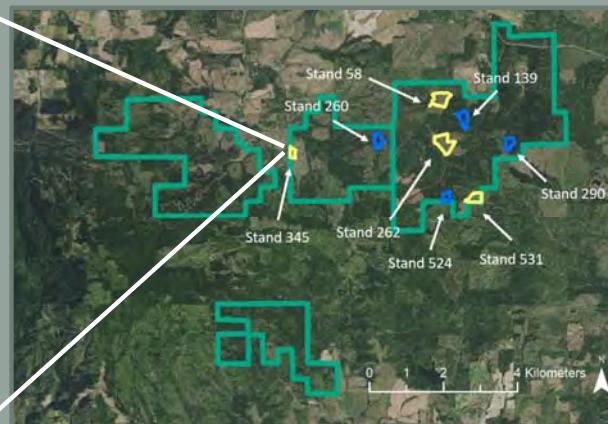
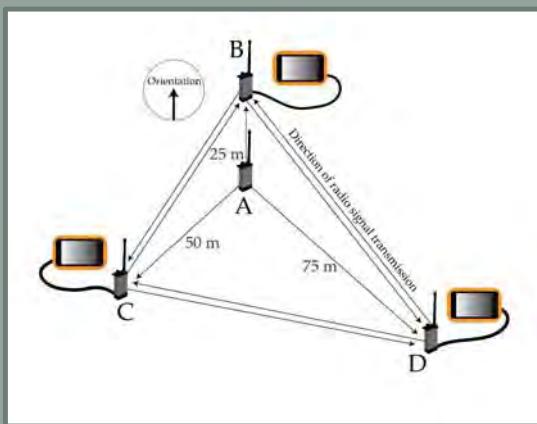


Article

## Characterizing Rigging Crew Proximity to Hazards on Cable Logging Operations Using GNSS-RF: Effect of GNSS Positioning Error on Worker Safety Status

Ann M. Wempe \* and Robert F. Keefe 

# AVOIDANCE: GEOFENCES



Article

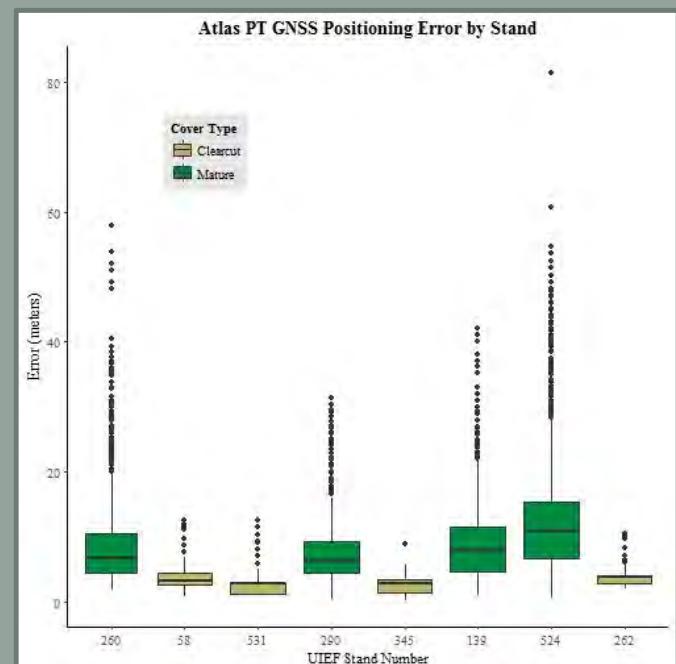
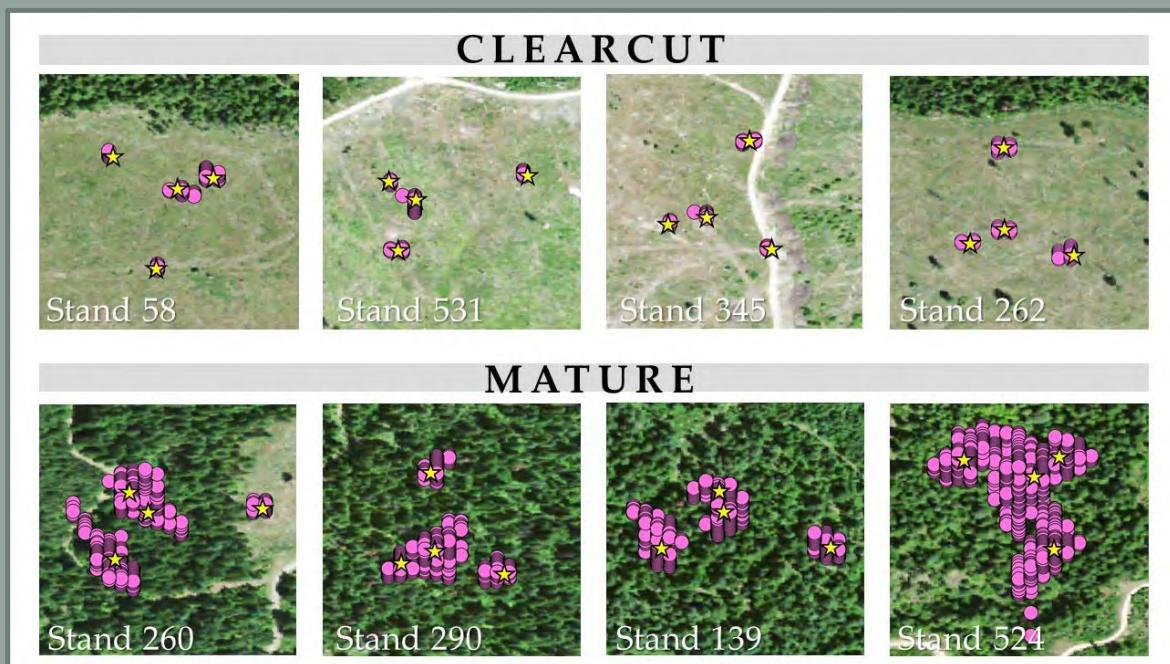
## Characterizing Rigging Crew Proximity to Hazards on Cable Logging Operations Using GNSS-RF: Effect of GNSS Positioning Error on Worker Safety Status

Ann M. Wempe \* and Robert F. Keefe 

Table 1. Controlled experiment: University of Idaho Experimental Forest stand characteristics and sampling conditions.

Stand	Cover	Mean Height (m)	Mean DBH (cm)	Azimuth (°)	Slope (%)	Date	Mean Satellites	Mean PDOP
260	Mature	23.52	33	95	37	10/12/16	7	1.6
58	Clearcut	NA	NA	352	18	10/17/16	8	1.3
531	Clearcut	NA	NA	165	35	10/19/16	8	1.4
290	Mature	14.6	25	35	5	10/19/16	7	1.5
345	Clearcut	NA	NA	130	8	10/24/16	10	1.3
139	Mature	16.7	31	347	43	10/24/16	6	1.6
524	Mature	17.3	31	27	14	11/10/16	6	1.7
262	Clearcut	NA	NA	205	2	11/17/16	8	1.2

# AVOIDANCE: GEOFENCES



# AVOIDANCE: GEOFENCES

RESEARCH ARTICLE

Real-time positioning in logging: Effects of forest stand characteristics, topography, and line-of-sight obstructions on GNSS-RF transponder accuracy and radio signal propagation

Eloise G. Zimbelman\*, Robert F. Keefe\*

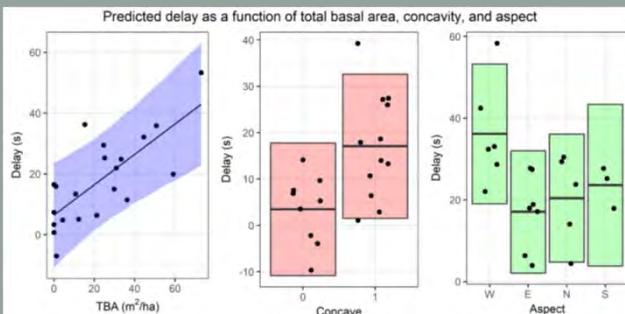


Fig. 5. Mixed-effects model predictions for geofence intersection alert delay. Predicted delay as a function of the three model variables (TBA, concave, and aspect). Predictions for each variable were made using the mean of the other predictors. 95% confidence intervals computed using the bootstrap are shown as colored bands. Points on each plot represent partial residuals.

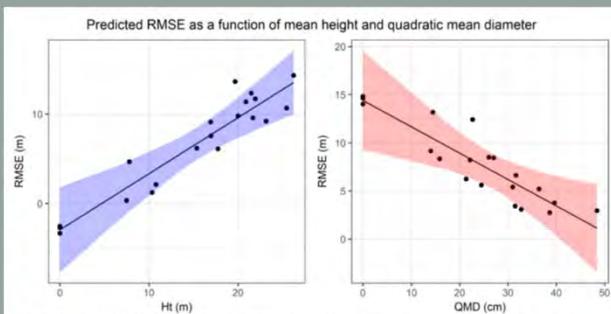
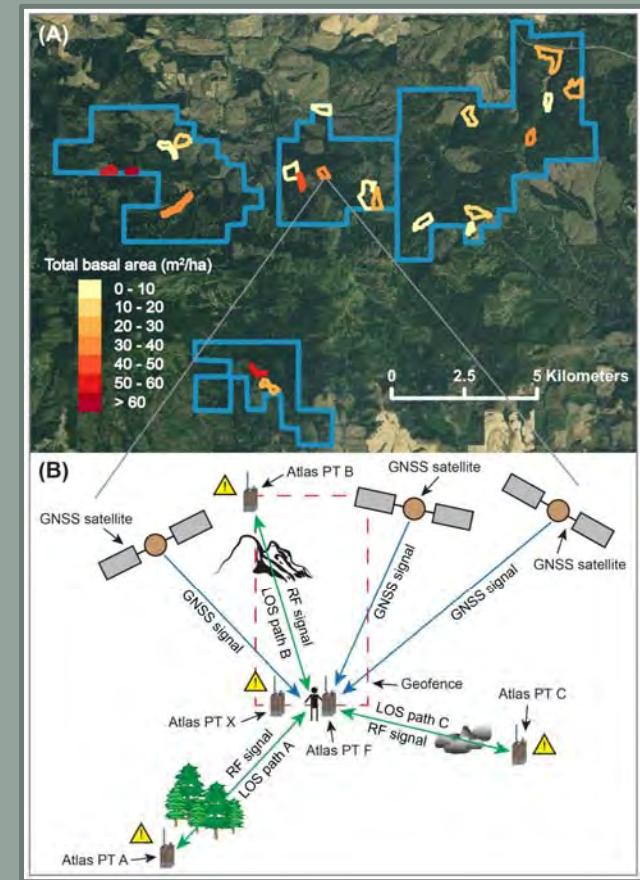


Fig. 4. Mixed-effects model predictions for PT RMSE. Predicted RMSE as a function of the two model variables (Ht and QMD). Predictions for each variable were made using the mean of the other predictor. 95% confidence intervals computed using the bootstrap are shown as colored bands. Points on each plot represent partial residuals.



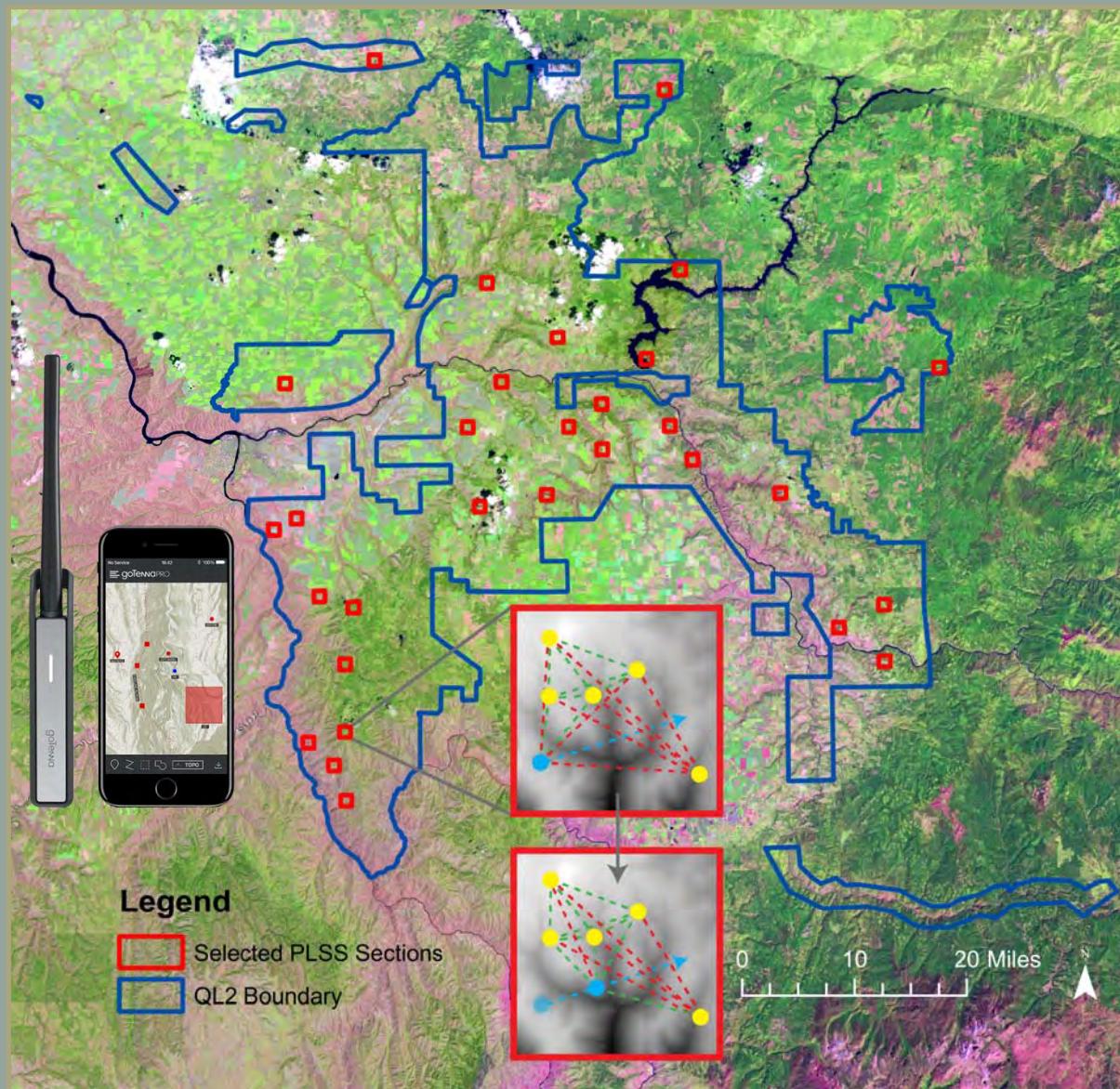
# AVOIDANCE

*Evaluating connectivity of smartphone-based mesh networks in irregular, forested terrain*

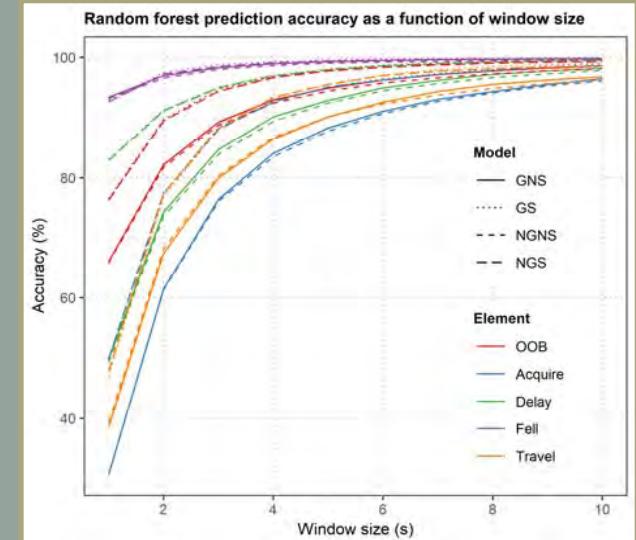
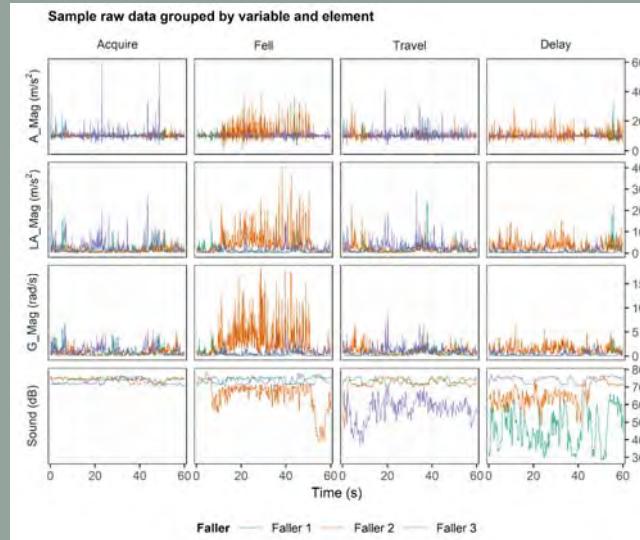
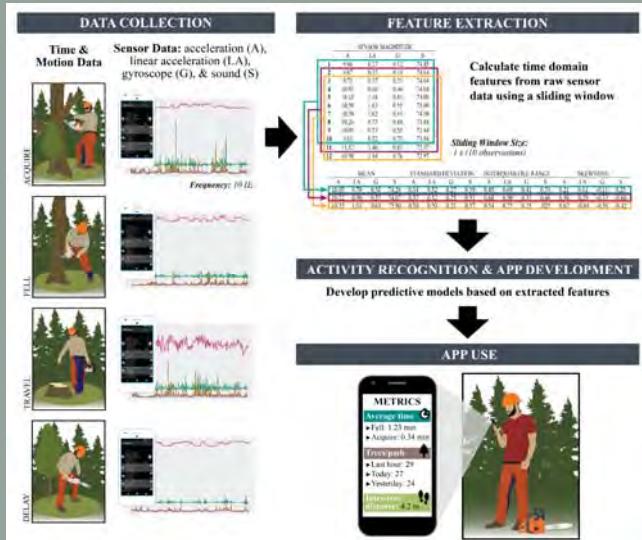
-30 Public Land Survey System (PLSS) sections: 1 mi<sup>2</sup> (260 ha)

-Selected based on LiDAR-derived rumple index (ratio between surface area and projected area)

- Exclude sections with rumple indices > 1.2 (limited accessibility) and sections that aren't within 10% of 260 ha
- Ranges from 1.00286–1.199872, divide into 5 categories and randomly select 6 sections from each



# DETECTION: ACTIVITY RECOGNITION

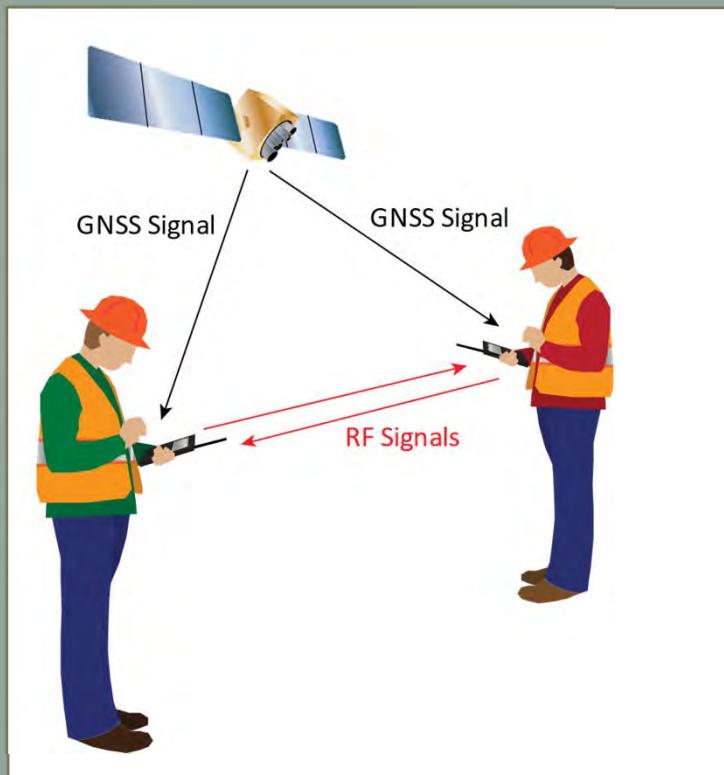


Use of smartphone sensors to quantify the productive cycle elements of hand fallers on industrial cable logging operations

Robert F. Keefe , Eloise G. Zimbelman and Ann M. Wempe

Department of Forest, Rangeland and Fire Sciences, University of Idaho, Moscow, ID, USA

# RESPONSE



# CONTRACTOR PERSPECTIVES



The faller could definitely see where the other guy that's working with him is, knows how far away he is.

People could notice that he's been sitting in the same spot for 15 minutes and the dot hasn't moved. We need to get over there and check on him.

The [yarder] operator a lot of times can't see his hookers down on the ground in the bottom of the strips. So yeah, I do think [GPS] could be beneficial in some areas. Particularly the line skidding operations.

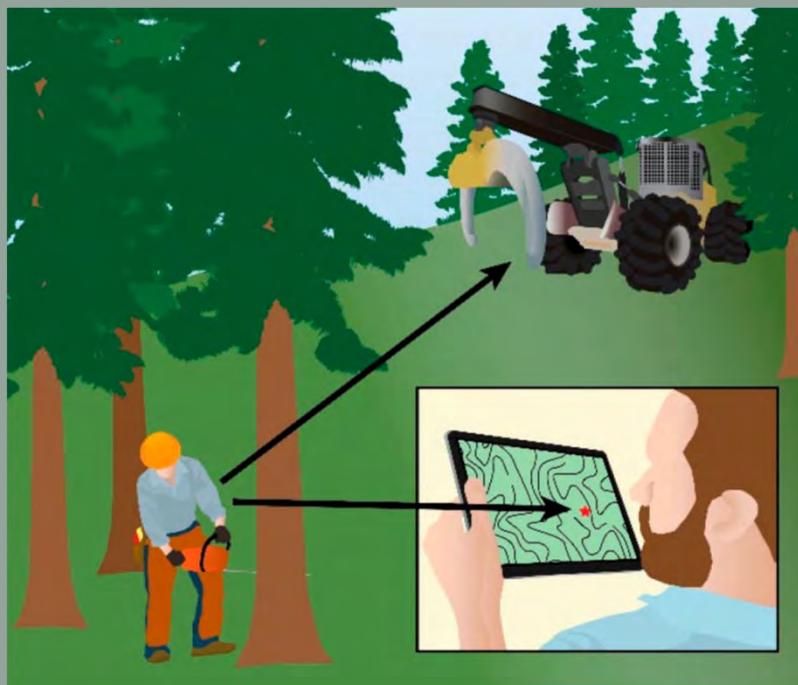
I'm sure there's been times that a buncher has fell timber a little closer to the skidder than what should be happening.

*Article*

## Human Factors Affecting Logging Injury Incidents in Idaho and the Potential for Real-Time Location-Sharing Technology to Improve Safety

Soren M. Newman <sup>1,\*</sup>, Robert F. Keefe <sup>2</sup>, Randall H. Brooks <sup>2</sup>, Emily Q. Ahonen <sup>3</sup> and Ann M. Wempe <sup>2</sup>

# CONTRACTOR PERSPECTIVES



*Article*

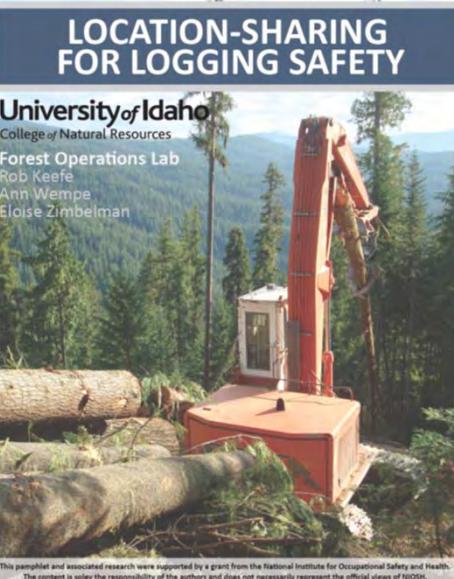
## Intent to Adopt Location Sharing for Logging Safety Applications

Ann M. Wempe <sup>1</sup>✉, Robert F. Keefe <sup>1,\*</sup>✉, Soren M. Newman <sup>2</sup>✉ and Travis B. Pavaglio <sup>3</sup>

# CONTRACTOR PERSPECTIVES

**LOCATION-SHARING FOR LOGGING SAFETY**

**University of Idaho**  
College of Natural Resources  
Forest Operations Lab  
Rob Keefe  
Ann Wempe  
Eloise Zimbelman



This pamphlet and associated research were supported by a grant from the National Institute for Occupational Safety and Health. The content is solely the responsibility of the authors and does not necessarily represent the official views of NIOSH.

**WHAT IS LOCATION-SHARING?**

Location-sharing devices can determine where they are from groups of satellites in the Global Navigation Satellite System (GNSS), such as the United States' Global Positioning System (GPS). They can then share their position with other mobile devices through cellular networks, satellite data communication, or radio transmission.

**Finding Your Location**

Satellites communicate via microwaves, which travel to Earth at the speed of light. Positioning devices receive these signals and determine the amount of time the signals traveled. With speed and time, a device can calculate its distance from the satellite's position. Knowing distances from multiple satellites allows the device to tell you where on the Earth's surface you are located.

**Sharing Your Location**

Your location can be shared with others through a radio frequency (RF) transmission and then mapped on a mobile device, such as a tablet or smartphone, so others can see where you are. GNSS-RF communication does not require cellular networks or an internet connection, so these location-sharing devices can be used off the grid in remote areas.

For more information contact: Rob Keefe  
roke@uidaho.edu • (208) 885-0749  
University of Idaho

**LOCATION-SHARING & LOGGING SAFETY**

**Where is everyone?**

Loggers could use location-sharing technology with a mobile device, to see the real-time locations of workers or equipment on a harvest map. Location sharing can help increase situational awareness of where everyone is in case of emergency.

**When do people need help?**

Many location-sharing devices allow users to send alerts when they need help, or devices may be able to send an automatic warning under certain conditions, such as when someone has not moved in a long time and may be hurt.

**When are people near hazards?**

Some devices are able to use virtual boundaries known as geofences to mark dangerous areas on logging operations and send alerts when someone has moved into a geofenced area. For example, a logger should receive a warning approach within two tree lengths of a hazard, or when members of the logging crew are unloading the skyline carriage. The accuracy of geofences in forested environments varies widely among available devices and technology; in use of proximity alerts for these kinds of safety applications should be used with caution. The most important safety benefit of location sharing is usually just being able to see the approximate, current positions of fellow crew members and equipment.

For more information contact: Rob Keefe  
roke@uidaho.edu • (208) 885-0749  
University of Idaho

**LOCATION-SHARING DEVICES**

	Beartooth	(mesh) goTenna	Sonnet	Garmin Rino 750	Raveon Atlas PT	TrellisWare Ghost	Garmin inReach SE*	SPOT Gen3*
Requires mobile device	✓	✓	✓		✓	✓	✓	✓
<b>SOS</b>	✓			✓		✓	✓	✓
<b>Texts</b>	✓	✓	✓	✓	✓	✓	✓	✓
<b>Voice</b>	✓	✓		✓		✓		
<b>Images</b>		✓				✓	✓	
<b>Videos</b>						✓		
<b>Position update</b>	manual	manual	30 sec	manual	3 sec	2-3 sec	2-30 min	24 hr
<b>Geofencing</b>						✓		
<b>Mesh networking</b>	✓	✓	✓			✓		
<b>Battery life</b>	4 days	24 hrs	24 hrs	34-38 hrs	24 hrs	8 hrs	70-300 hrs	10+ days
<b>Range**</b>	5 m (line of sight) 30 m (max) (150 hrs max)	8 m (max) 30 m (max)	0.3-4 mi	20 mi	30 mi	26 m (max) (8 hr max)	global	global
<b>Price</b>	\$1296/2 \$400/10	\$1180/2 \$1180/9	\$550	\$1,800	\$4,200	\$1170 + monthly subscription	\$1170 + monthly subscription	\$1170 + monthly subscription

\*satellite-based communication  
\*\*advertised ranges - actual ranges will vary

For more information contact: Rob Keefe  
roke@uidaho.edu • (208) 885-0749  
University of Idaho

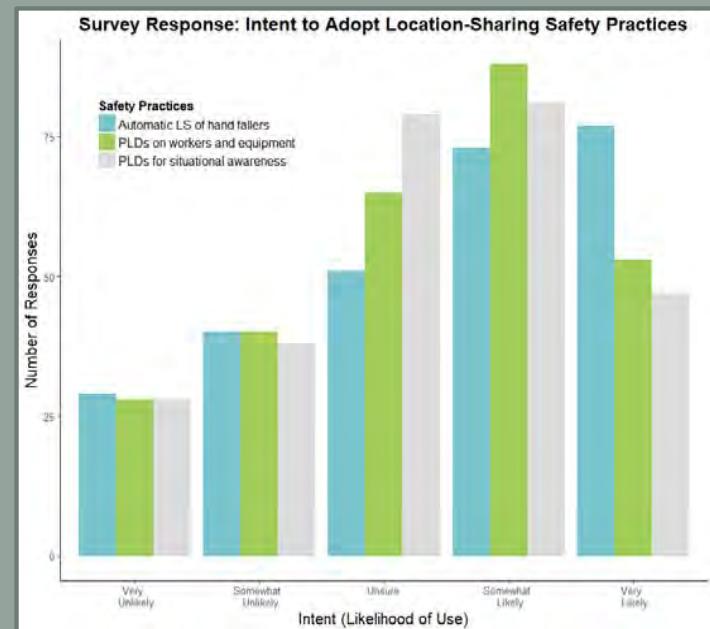
Article

## Intent to Adopt Location Sharing for Logging Safety Applications

Ann M. Wempe <sup>1</sup>✉, Robert F. Keefe <sup>1,\*</sup>✉, Soren M. Newman <sup>2</sup>✉ and Travis B. Pavaglio <sup>3</sup>

# CONTRACTOR PERSPECTIVES

	Response Percentage (%)		
	No	Unsure	Yes
<b>Previous use of LS devices</b>			
Emergency receivers (n=271)	91.5	1.8	6.6
2-way radios (n=270)	79.3	1.1	19.6
Smartphone receivers (n=271)	87.8	1.1	11.1
<b>Improvement to safety by device</b>			
Emergency receivers (n=263)	16.0	20.5	63.5
2-way radios (n=269)	8.6	12.6	78.8
Smartphone receivers (n=272)	14.0	14.0	72.1
<b>Improvement to safety by feature</b>			
Hazardous area alerts (n=277)	11.9	11.2	76.9
Automatic updates to coworkers (n=275)	13.1	14.2	72.7
Automatic updates to supervisors (n=271)	47.2	18.8	33.9
Help button to coworkers (n=275)	7.3	9.5	83.3
Help button to supervisors (n=274)	24.1	13.5	62.4
Help button to emergency services (n=276)	8.3	12.7	79.0
Messaging (n=273)	12.8	15.0	72.2
<b>Privacy concerns associated with LS</b>			
Coworkers (n=276)	72.5	8.7	18.8
Supervisors (n=273)	56.0	11.4	32.6
<b>Smartphone ownership (n=279)</b>	27.6	NA	72.4



Article

## Intent to Adopt Location Sharing for Logging Safety Applications

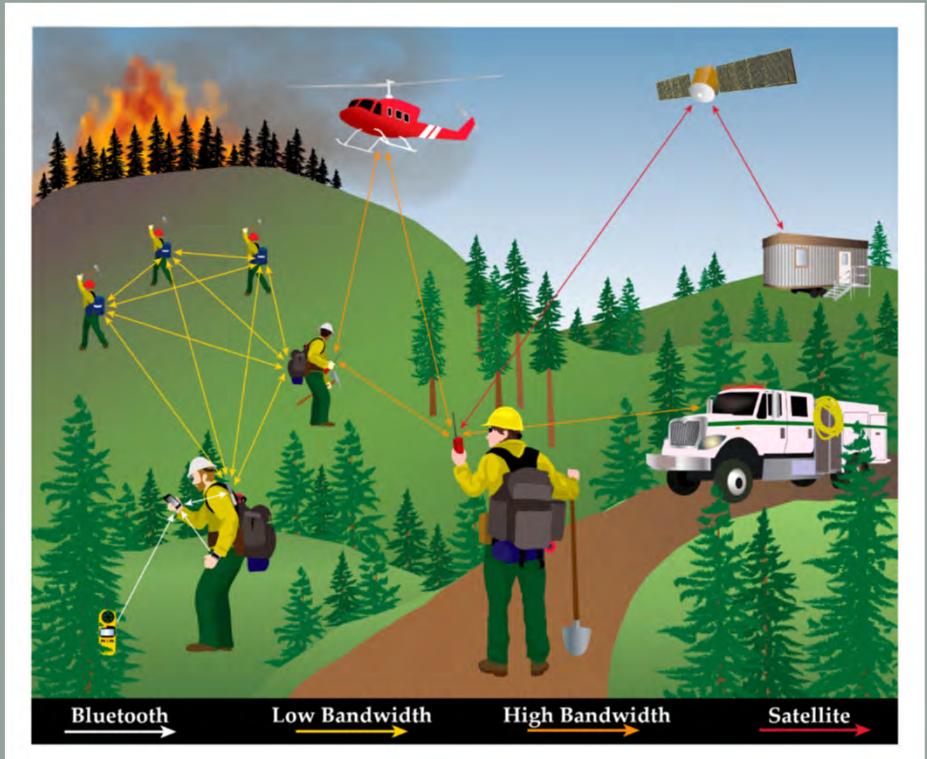
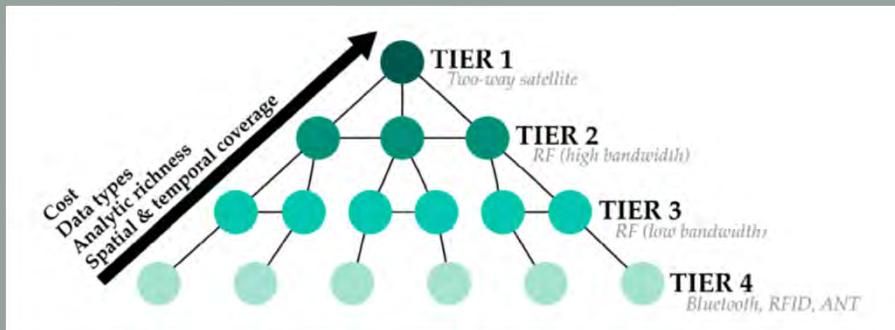
Ann M. Wempe <sup>1</sup> , Robert F. Keefe <sup>1,\*</sup> , Soren M. Newman <sup>2</sup>  and Travis B. Pavaglio <sup>3</sup>

# DISCUSSION

1. Accuracy, data rates, device size, etc. depend on application (prevention, detection, response)
2. GPS/GNSS-based solutions for *prevention* should be used for broad situational awareness and not for detailed proximity alerts in the woods
3. Good support among loggers for technology-based solutions to improve safety. We have a very positive, continuing dialog among researchers and contractors
4. Integration of location and activity data into digital health may be useful for increasing SA to improve safety in rural occupations
5. Commercially available mesh RF and satellite devices are useful solutions for different applications— Both are evolving quickly



# DISCUSSION



Keefe, R.F., Wempe, A.M., Becker, R.M., Zimbelman, E.G., Nagler, E.G., Gilbert, S.M. and C. Caudill. Positioning methods and the use of location and activity data in forests. *Forests*

# QUESTIONS?

Rob Keefe, Ph.D.

Associate Professor of Forest Operations

Director and Forest Manager, UI Experimental Forest

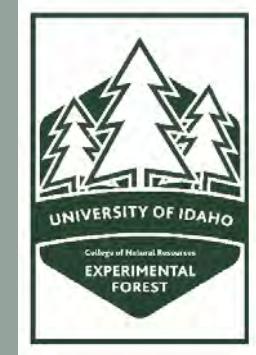
Moscow, ID, 83844-3322

[robk@uidaho.edu](mailto:robk@uidaho.edu)

(208) 310-0269



**This work was funded primarily by NIOSH cooperative agreement 5 U01 OH010841: Reducing logging fatality and non-fatal trauma incidence rates with new real-time operational GPS-RF communications and safety procedures.**



**Contributors include, among others, Eloise Zimbelman, Ann Wempe, Soren Newman, Jan Eitel, Travis Paveglio, Emily Nagler, Eva Strand, Crystal Kolden, and Randall Brooks**