August 11-13, 2009

2nd International Symposium on Resilient Control Systems

ISRCS 2009

University of Idaho

Idaho State University

INL
Idaho National Laboratory

ies

IEEE

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Welcome to ISRCS 2009

Purpose of ISRCS 2009

The major purpose of this symposium is to communicate, discuss, and further develop these high level visions and ideas via community participation and to vet, modify, extend, and endorse particular concepts that will lead to research needs definitions. Desired product of the symposium is the publication of proceedings for these identified concepts that will set the stage for task group execution, identification and engagement of funding sponsors, and the identification of future research strategies and products.

There will be two tracks for this year's symposium, with control systems and control theory sessions included under these tracks:

- Human Systems – The human ability to quickly understand novel situations, employ heuristics and analogy can provide additional control system resilience; however, complexity, environment and individual elements can affect this ability.
- Cyber Awareness – Because of the human element of a malicious actor, traditional methods of achieving reliability cannot be used to characterize cyber awareness and resilience. Novel techniques in characterizing wellness and randomizing system response to the adversary are needed.

ISRCS Tutorials and Training

Security, Human Performance, and Resilience

The Instrumentation, Control, and Intelligent System's group invites the ISRCS 2009 attendees to attend the symposium's one day tutorial on August 11th for an overview of control system security, human performance, and resilience. The tutorial will begin by providing an introductory discussion of control system hardware, software, and the role of human factors. This will be followed by more focused lectures on software vulnerabilities and inherent human vulnerabilities which may be exploited by the adversary. The tutorial will then proceed to a more in-depth discussion of relevant aspects of human performance and organizational resilience. We will then close with short discussion of the path forward for realizing resilient control systems.

Paper Tracks

Although two tracks are given, control theory and control systems are included under topics for special sessions to gather architecture and automation perspectives.

Human Systems

Track Chair: Ron Boring, Sandia National Laboratories
Track Co-Chair: David Gertman, Idaho National Laboratory

The human ability to quickly understand novel situations, employ heuristics and analogy can provide additional control system resilience. On the other hand there are situations in which we may have a general inability to reproducibly predict human behavior. This may be true in situations of fatigue or high stress or decision making under high levels of uncertainty. Bayesian methods provide one method by which to take into account evidence regarding human response, but this is one among many approaches. The literature in human reliability analysis provides an orientation regarding ergonomics, workload, complexity, training, experience, etc., which may be used to characterize and quantify human actions and decisions.

Digital technology, used to benefit control system interaction, can from the operators perspective, provide additional complexity. For example, more information can be presented to the human operator to base a response. However, the response could be completely automated, human manipulated, or a combination of both. The dependencies and rules for these complex interactions, or mixed initiative, are not necessarily well defined or clear. Resiliency results from understanding of this complexity, ensuring through human factor and design an error tolerant control system results that complements perception, fusion, and decision making.

Cyber Awareness:

Track Chair: Eugene Santos, Dartmouth College
Track Co-Chair: Miles McQueen, Idaho National Laboratory

Because of the human element of a malicious actor, traditional methods of achieving reliability cannot be used to characterize cyber awareness and resilience. The intellectual level and background of the adversary makes stochastic methods unusable due to the randomness of both the objective and the motives. However, the strength of the adversary is increased because the existing control system architecture is not random, and response characteristics are reproducible. Therefore, a resilient design can find strength in similar fashion by becoming atypical of normal control system architectural design, and appearing random in response and characteristics to the adversary.

Characterization of health or wellness from a cyber perspective is purely empirical, as prediction of the future is based on past events. While there are barriers in place to exclude known types of adversarial communication, state awareness cannot be assured because of the limited availability of diverse sensing. Determination of the actual cause of an abnormal event can only occur only after forensics is completed. Patterns or routines are analyzed and are used to provide comparisons to understand anomalies. However, while this understanding provides an interesting perspective, it is very limited in predicting future behavior of the adversary.

Panel Discussions

Parallel panel discussions in both the human systems and cyber awareness areas will be performed during the symposium, allowing a distinguished group of individuals from academia, government and industry to address topical questions developed beforehand. For each question asked, both the panelists and audience will be allowed to contribute. The panel discussion will conclude with an opportunity for each panelist to provide closing remarks, and the audience to ask direct questions of the panelists. The facilitated sessions will be documented and posted for future reference by symposium participants.

Daily Agenda

Tuesday, August 11 - *Tutorials and Training*

CHE 211 *(Unless otherwise noted)*

7:00 a.m.	**Registration**
7:30 a.m.	**Welcome, Introductions and Logistics**
8:00 a.m.	**Tutorial Overview**
8:15 a.m.	**Session 1** Control System Software, Hardware, Resilience and Human Factor
9:45 a.m.	**Break** (CHE 213)
10:15 a.m.	**Session 2** HW/SW Vulnerabilities
12:00 p.m.	**Hosted Lunch** (Student Union Building – Multipurpose Room)
1:00 p.m.	**Session 3** Human Vulnerabilities
2:30 p.m.	**Break** (CHE 213)
3:00 p.m.	**Session 4** Human Factors
5:00 p.m.	**Path Forward:** Resilience, Where Do We Go From Here?
5:15 p.m.	**Adjourn for the day**
6:00 p.m.	**Sponsored Working Dinner at CAES** Special invitation only (Business Casual)

** Poster Sessions will be ongoing throughout the conference. CHE 213*

Wednesday, August 12 - *Paper Tracks*

CHE 211 *(Unless otherwise noted)*

7:45 a.m.	**Daily Agenda**
8:00 a.m.	**Keynote 1: Fundamentals to Engineer Resilient Systems:** **How Adaptive Systems Fail and the Quest for Polycentric Control Architectures** by David Woods, The Ohio State University
9:00 a.m.	**Keynote 2: Security Economics and Critical National Infrastructure** by Ross Anderson, Cambridge University
10:00 a.m.	**Break** (CHE 213)
10:30 a.m.	**Human Systems/Cyber Awareness Papers**
12:30 p.m.	**Hosted Lunch** (Student Union Building – Multipurpose Room)
1:30 p.m.	**Leave for CSAC DEMO** 765 Lindsay Blvd Idaho Falls, ID
5:30 p.m.	**Adjourn until Social**
6:30 p.m.	**Hosted Social at Art Museum of Eastern Idaho** (Business Casual)

Daily Agenda *Continued*

Thursday, August 13 - *Panel Discussions*

CHE 211 *(Unless otherwise noted)*

7:45 a.m.	**Daily Agenda**
8:00 a.m.	**Keynote 3: The Architecture of Robust, Evolvable Networks** by John Doyle, Caltech
9:00 a.m.	**Keynote 4: North American Bulk Power System: Need for Resilient and Secure Designs** by Michael Assante, North American Electric Reliability Corporation
10:00 a.m.	**Break**
10:30 a.m.	(CHE 215) **Panel Discussion on Human Systems**
	(CHE 216) **Panel Discussion on Cyber Awareness**
12:30 p.m.	**Thanks, Concluding Comments, and Next Year**
12:35 p.m.	**Adjourn Symposium**

Friday, August 14 - *Yellowstone Lower Loop Tour*

**Schedule subject to change based on group/tour guide preferences*

6:00 a.m.	Meet at AmeriTel Inn
6:15 a.m.	Meet at Shilo Inn
6:30 a.m. – 8:30 a.m.	Drive to Yellowstone IMAX meet up with Xanterra tour guide
8:30 a.m. – 12:00 p.m.	Canyon, Hayden Valley, other sightseeing ** Yellowstone Dollars will be provided for lunch*
12:00 p.m. – 1:30 p.m.	Lunch at Lake Village
3:00 p.m. – 6:00 p.m.	Old Faithful Paint Pots, other sightseeing
6:00 p.m.	Return back to hotels

Fundamentals to Engineer Resilient Systems: How Adaptive Systems Fail and the Quest for Polycentric Control Architectures

David D. Woods, The Ohio State University

Engineering resilience is possible because of advances in the theory of complex adaptive systems, the insights gathered from observations of high-reliability organizations, and the results from studies of how people adapt to make systems work despite complexity. Based on these results, the talk will present a taxonomy of how adaptive systems fail. Case studies from emergency situations (urban firefighting, emergency medicine, aerospace, disaster management) will be used to illustrate the key first principles of resilience and the basic forms of breakdown in adaptive systems. The forms of breakdown provide criteria and concepts to guide the development of polycentric control architectures to manage the resilience of distributed, multi-echelon systems.

DAVID D. WOODS is Professor of Integrated Systems Engineering at the Ohio State University. A pioneer in Cognitive Systems Engineering for human-computer decision making in emergencies, he is past president and a fellow of the Human Factors and Ergonomic Society, and a fellow of the Association for Psychological Science and the American Psychological Association. He is co-recipient of the Ely Award for best paper in the journal Human Factors (1994) and the Laurels Award from Aviation Week and Space Technology (1995) for research on the human factors of highly automated cockpits, the Jack Kraft Innovators Award from the Human Factors and Ergonomics Society (2002), an IBM Faculty Award (2005), and a Google Faculty Award (2008). Dr. Woods has served on National Academy of Science and other advisory committees including Aerospace Research Needs (2003), Engineering the Delivery of Health Care (2005), and Dependable Software (2006). He has testified to U.S. Congress on Safety at NASA and on Election Reform. He has worked extensively at the intersection of engineering and health care as a board member of the National Patient Safety Foundation (1996-2002) and as Associate Director of the Midwest Center for Inquiry on Patient Safety of the Veterans Health Administration. He is coauthor of Behind Human Error (1994; second edition, in press), A Tale of Two Stories: Contrasting Views of Patient Safety (1998), Joint Cognitive Systems: Foundations of Cognitive Systems Engineering (2005), and Joint Cognitive Systems: Patterns in Cognitive Systems Engineering (2006). He has investigated accidents in nuclear power, aviation, space, and anesthesiology, and was an advisor to the Columbia Accident Investigation Board. A new direction in his research on safety is how to engineer resilience into systems that manage high risk processes; he is co-editor of books -- Resilience Engineering (2006); Resilience Engineering in Practice (in press) and 20 publications on this topic.

Security Economics and Critical National Infrastructure

Ross Anderson, Cambridge University

One of the most exciting developments in security research since 2000 has been the emergence of security economics as a discipline. Many security failures can be traced to inappropriate incentives rather than to technical errors, and the application of techniques from microeconomics and game theory has shed new light on a number of problems that were previously considered intractable. There are now over 100 people working in the field, and it's producing interesting results in all sorts of areas from the patching cycle through modeling the return on investment to optimal regulation. Security economics has particular relevance to critical national infrastructure, many of whose problems have to do with business models, regulation and liability.

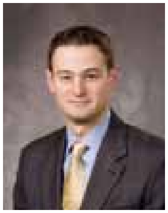
ROSS ANDERSON is Professor of Security Engineering at Cambridge University. He is one of the founders of a vigorously-growing new academic discipline, the economics of information security. Ross was also a seminal contributor to the idea of peer-to-peer systems and an inventor of the AES finalist encryption algorithm "Serpent". He also has well-known publications on many other technical security topics including hardware tamper-resistance, emission security, copyright marking, and the robustness of application programming interfaces (APIs). He is a Fellow of the Royal Society, the IET and the IMA. He also wrote the standard textbook "Security Engineering - a Guide to Building Dependable Distributed Systems"

The Architecture of Robust, Evolvable Networks

John Doyle, CalTech

Biological systems are robust and evolvable in the face of even large changes in environment and system components, yet can simultaneously be extremely fragile to small perturbations. Such universally robust yet fragile (RYF) complexity is found wherever we look. The amazing evolution of microbes into humans (robustness of lineages on long timescales) is punctuated by mass extinctions (extreme fragility). Diabetes, obesity, cancer, and autoimmune diseases are side-effects of biological control and compensatory mechanisms so robust as to normally go unnoticed. RYF complexity is not confined to biology. The complexity of technology is exploding around us, but in ways that remain largely hidden. Modern institutions and technologies facilitate robustness and accelerate evolution, but enable catastrophes on a scale unimaginable without them (from network and market crashes to war, epidemics, and global warming). Understanding RYF means understanding architecture — the most universal, high-level, persistent elements of organization — and protocols. Protocols define how diverse modules interact, and architecture defines how sets of protocols are organized. Insights into the architectural and organizational principles of networked systems can be drawn from three converging research themes. 1) With molecular biology's description of components and growing attention to systems biology, the organizational principles of biological networks are becoming increasingly apparent. Biologists are articulating richly detailed explanations of biological complexity, robustness, and evolvability that point to universal principles. 2) Advanced technology's complexity is now approaching biology's. While the components differ, there is striking convergence at the network level of architecture and the role of layering, protocols, and feedback control in structuring complex multiscale modularity. New theories of the Internet and related networking technologies have led to test and deployment of new protocols for high performance networking. 3) A new mathematical framework for the study of complex networks suggests that this apparent network-level evolutionary convergence within/between biology/technology is not accidental, but follows necessarily from the universal system requirements to be efficient, adaptive, evolvable, and robust to perturbations in their environment and component parts.

JOHN DOYLE is the John G Braun Professor of Control and Dynamical Systems, Electrical Engineer, and Bio-Engineering at Caltech. He has a BS and MS in EE, MIT (1977), and a PhD, Math, UC Berkeley (1984). Current research interests are in theoretical foundations, for complex networks in engineering and biology, focusing on architecture, and for multiscale physics. Early work was in the mathematics of robust control, including LQG robustness, (structured) singular value analysis, H-infinity plus recent extensions to nonlinear and hybrid systems. His research group has collaborated in many software projects, including the Robust Control Toolbox (muTools), SOSTOOLS, SBML (Systems Biology Markup Language), and FAST (Fast AQM, Scalable TCP). Prize paper awards include the IEEE Baker, the IEEE Automatic Control Transactions Axelby (twice), and best conference papers in ACM Sigcomm and AACC American Control Conference. Individual awards include the AACC Eckman, and the IEEE Control Systems Field and Centennial Outstanding Young Engineer Awards. He has held national and world records and championships in various sports.



North American Bulk Power System: Need for Resilient and Secure Designs

Michael Assante, North American Electric Reliability Corporation (NERC)

MICHAEL J. ASSANTE is Vice President and Chief Security Officer of the North American Electric Reliability Corporation (NERC), effective August, 2008. Mr. Assante comes to NERC from the Department of Energy’s Idaho National Laboratory (INL) as a widely recognized expert and visionary in the fields of security and infrastructure protection. Mr. Assante also presently serves as a sitting member of the Commission on Cyber Security for the 44th Presidency of the United States. Prior to assuming his strategic leadership position at INL, Mr. Assante was a vice president and Chief Security Officer at American Electric Power, one of the largest generators of electric power in the U.S.

A Host-Based Security Assessment Architecture for Industrial Control Systems

Abhishek Rakshit & Xinming Ou

Computerized control systems perform vital functions across many critical infrastructures throughout the nation. These systems can be vulnerable to a variety of attacks leading to devastating consequences like loss of production, interruption in distribution of public utilities and most importantly endangering public safety. This calls for an approach to halt attacks in their tracks before being able to do any harm to these systems. Vulnerability assessment performed on these systems can identify and assess potential vulnerabilities in a control system network, before they are exploited by malicious intruders. Effective vulnerability assessment architecture should assimilate security knowledge from multiple sources to uncover all the vulnerabilities present on a host. Legitimate concerns arise since host-based security scanners typically need to run at administrative privileges, and takes input from external knowledge sources for the analysis. Intentionally or otherwise, ill-formed input may compromise the scanner and the whole system if the scanner is susceptible to, or carries one or more vulnerability itself. This paper presents an architecture where a host-based security scanner's code base can be minimized to an extent where its correctness can be verified by adequate vetting. At the same time, the architecture also allows for leveraging third-party security knowledge efficiently and supports various higher-level security analyses.

A Passivity-Based Framework for Resilient Cyber Physical Systems

Nicholas Kottenstette, Gabor Karsai & Janos Sztipanovits

Resilient control systems play a special role in the area of cyber-physical systems, where the design must address the question how complex dynamic plants are to be controlled safely and reliably when a control system that is under a cyber attack. In this paper we describe a control theoretical framework based on the concept of passivity for designing a control network which can tolerate, for instance, denial-of-service attacks on networks used in the closed loop. In particular, we demonstrate how the resilient power junction structure could be applied, and show simulated results.

Human Reliability Analysis for Upgrades

Ronald Boring & Johanna Oxstrand

This paper presents work in progress on a project to develop a process for integrating human reliability analysis (HRA) into the design process used in nuclear power plant modernization and upgrade projects. Human factors and design experts were interviewed, resulting in six principles for the use of HRA in design. These principles are: (i) early implementation, (ii) tailored methods, (iii) scalable methods, (iv) better use of qualitative information, (v) HRA design criteria, and (vi) better HRA sensitivity to human-machine interface issues. Future efforts will center on adapting HRA techniques to meet these principles and implementing HRA as part of a plant upgrade process.

A Lightweight Software Control System for Cyber Awareness and Security

Michele Co, Clark Coleman, Jack Davidson, Sudeep Ghosh, Jason Hiser, John Knight & Anh Nguyen-Tuong

Designing and building software that is free of defects that can be exploited by malicious adversaries is a difficult task. Despite extensive efforts via the application of formal methods, use of automated software engineering tools, and performing extensive pre-deployment testing, exploitable errors still appear in software. The problem of cyber resilience is further compounded by the growing sophistication of adversaries who can marshal substantial resources to compromise systems. This paper describes a novel, promising approach to improving the resilience of software. The approach is to impose a process- level software control system that continuously monitors an application for signs of attack or failure and responds accordingly. The system uses software dynamic translation to seamlessly insert arbitrary sensors and actuators into an executing binary. The control system employs the sensors to detect attacks and the actuators to affect an appropriate response. Using this approach, several novel monitoring and response systems have been developed. The paper describes our lightweight process-level software control system, our experience using it to increase the resilience of systems, and discusses future research directions for extending and enhancing this powerful approach to achieving cyber awareness and resilience.

Computationally Efficient Neural Network Intrusion Security Awareness

Todd Vollmer & Milos Manic

An enhanced version of an algorithm to provide anomaly based intrusion detection alerts for cyber security state awareness is detailed. A unique aspect is the training of an error back-propagation neural network with intrusion detection rule features to provide a recognition basis. Network packet details are subsequently provided to the trained network to produce a classification. This leverages rule knowledge sets to produce classifications for anomaly based systems. Several test cases executed on ICMP protocol revealed a 60% identification rate of true positives. This rate matched the previous work, but 70% less memory was used and the run time was reduced to less than 1 second from 37 seconds.

Bayesian Inference for Fault-Tolerant Control

Kris Villez, Shankar Narasimhan & Venkat Venkatasubramanian

A research line has been recently set up in view of resilient control for complex systems. In the first milestones of the project, we aim at the implementation of the Fault-Tolerant Control (FTC) technique developed in Prakash et al. (2002, 2005). While promising, this technique does not account for uncertainty in the model. Given that an accurate model may be difficult to establish, the method will be extended in such a fashion that structural and parametric uncertainties can be dealt with. In this contribution, we explain how Bayesian statistics are applied to deal with parametric uncertainties in the context of the original FTC technique. Despite our aim at complex system, the theory and application is developed and evaluated first for a simple CSTR model.

The VIKING Project: An Initiative on Resilient Control of Power Networks

By Annarita Giani

This paper presents the work on resilient and secure power transmission and distribution developed within the VIKING (Vital Infrastructure, networKs, INformation and control system ManaGement) project. VIKING receives funding from the European Community's Seventh Framework Program. We will present the consortium, the motivation behind this research, the main objective of the project together with the current status.

Extreme Point Result for Robust Stability of Interval Polynomials to the Special Left Sector

By Hwan Kang

In this paper, we consider robust stability of interval polynomials of which stability region is the special left sector. The argument of the boundary of the special left sector is expressible as an irrational number multiplied by the circle ratio. We show that a family of interval polynomials is robustly stable if and only if a small set of vertex polynomials are robustly stable. This new result comes from the construction algorithm of the value set and the zero exclusion principle.

Intelligent Neural Network Implementation for SOCI development of Li/CFx Batteries

By Ondrej Linda

The State Of Charge Indicator (SOCI) for the Lithium Poly Carbon Monoflouride (Li/CFx) battery has a wide range of applications. However, the dynamic environmental conditions, such as the ambient temperature, can alter the characteristic response of the battery and introduce non-linear behavior. This paper discusses the in-lab development of an Artificial Neural Network (ANN) based SOCI for the Li/CFx battery. The ANN is trained on the recorded data – voltage, current and ambient temperature, to produce a non-linear model and to accurately predict the State Of Charge (SOC) of the battery. The SOC prediction is based on the recent behavior of the battery. Preliminary experimental results using recorded datasets from the Battery Design Studio are presented for the Lithium Ion battery. The working model for the Li/CFx is currently under development. The reported results demonstrated good performance of the developed SOCI, with less than 2% average relative error on data at previously observed ambient temperatures.

Time Synchronization in Hierarchical TESLA Wireless Sensor Networks

By Jason Wright

Time synchronization and event time correlation are important in wireless sensor networks. In particular, time is used to create a sequence events or time line to answer questions of cause and effect. Time is also used as a basis for determining the freshness of received packets and the validity of cryptographic certificates. This paper presents secure method of time synchronization and event time correlation for TESLA-based hierarchical wireless sensor networks. The method demonstrates that events in a TESLA network can be accurately timestamped by adding only a few pieces of data to the existing protocol.

Phase-Space Reconstruction: A Path Towards the Next Generation of Nonlinear Differential Equation Based Models and Its Implications Towards Non-Uniform Sampling Theory

By Charles Tolle

This paper explores the overlaps between the Control community's work on System Identification (SysID) and the Physics, Mathematics, Chaos, and Complexity communities' work on phase-space reconstruction via time-delay embedding. There are numerous overlaps between the goals of each community. Nevertheless, the Controls community can gain new insight as well as some new very powerful tools for SysID from the latest developments within the Physics, Mathematics, Chaos, and Complexity communities. These insights are gained via the work on phase-space reconstruction of non-linear dynamics. New methods for discovering non-linear differential based equations that evolved from embedding operations can shed new light on hybrid-systems theory, Nyquest-Shannon's Theories, and network based control theory. This paper strives to guide the Controls community towards a closer inspection of the tools and additional insights being developed within the Physics, Mathematics, Chaos, and Complexity communities for discovery of system dynamics, the first step in control system development. The paper introduces the concepts of phase-space reconstruction via time-delay embedding (made famous by Whitney, Takens, and Sauer's Thoreoms), intergrate-and-fire embedding, and non-linear differential equation discovery based on Perona's method.

Conference Information

ISRCS Committees

Symposim Leadership Team

- Craig Rieger, Symposium Chair, INL
- Michelle Blacker, ISRCS Secretary, INL
- Ronald Boring, Track Chair, Sandia National Laboratories
- David Gertman, Track Co-chair, INL
- Milos Manic, Symposium Co-Chair, University of Idaho
- Miles McQueen, Track Co-chair, INL
- Eugene Santos, Track Chair, Dartmouth College

Technical Program Committee

- Azad Azadmanesh, University of Nebraska, Omaha
- Diane Hooie, NETL
- Axel Krings, University of Idaho
- Parag Lala, Texas A&M
- Thomas Larson, INL
- Kevin Moore, Colorado School of Mines
- Raghunathan Rengasamy, Clarkson University
- Juan Jose Rodriguez Andina, University of Vigo
- Marco Schoen, Idaho State University
- Charles Tolle, South Dakota School of Mines and Technology
- Zachary Tudor, SRI International

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- Subbaram Naidu, Idaho State University

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- Andrew Thomas, ISRCS Logistics
- Margie Jeffs, ISRCS Lead Facilitator
- Darcie Martinson, ISRCS Facilitator
- Desiree Reagan, ISRCS Web Developer
- Krista Griffin, ISRCS Support
- Kristyn St. Clair, ISRCS Program

Emergency Contacts

In case of medical emergency call 911

ISRCS Contacts

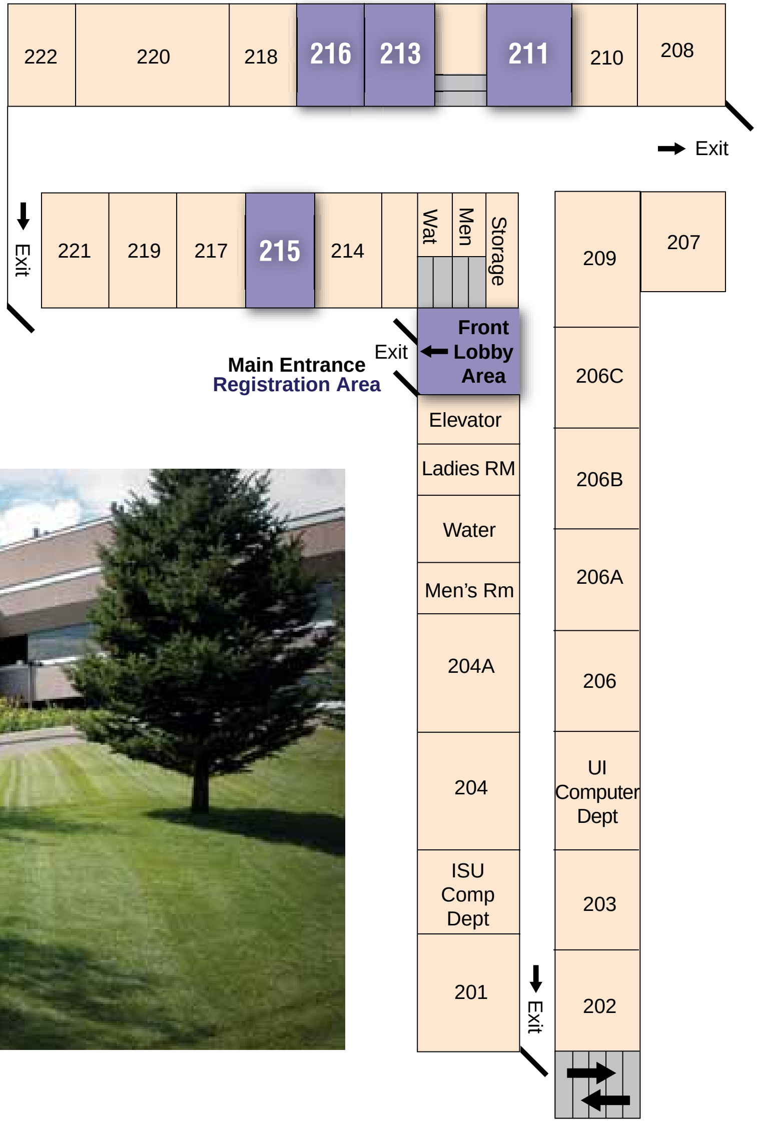
- Craig Rieger – 208.851.8839
- Michelle Blacker – 208.757.7642

Local Hospital

Eastern Idaho Regional Medical Center (EIRMC)
3100 Channing Way
Idaho Falls, ID 83404
208.529.6111

Main Level 2

CHE 211 – All Group Meetings
CHE 213 – Break room and Poster Sessions
CHE 215 – Human Systems
CHE 216 – Cyber Awareness



Yellowstone Tour Information

Yellowstone Tour

The guided Lower Loop Tour is a day-long trek that travels the lower portion of Yellowstone National Park's famous figure "8" road system.

Tour highlights include Old Faithful and Upper Geyser Basin, the bubbling mud pots of Fountain Paint Pots, the striking colors of the Grand Canyon of the Yellowstone with the 308-foot Lower Falls, and Yellowstone Lake, the largest alpine lake in North America. Stops typically include walking 1/2 to one mile around boardwalks and developed areas.

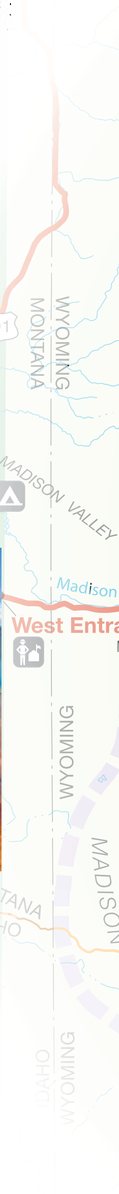
Walking times and distances may vary depending on the group's preferences. There also may be stops for wildlife viewing and other smaller features.

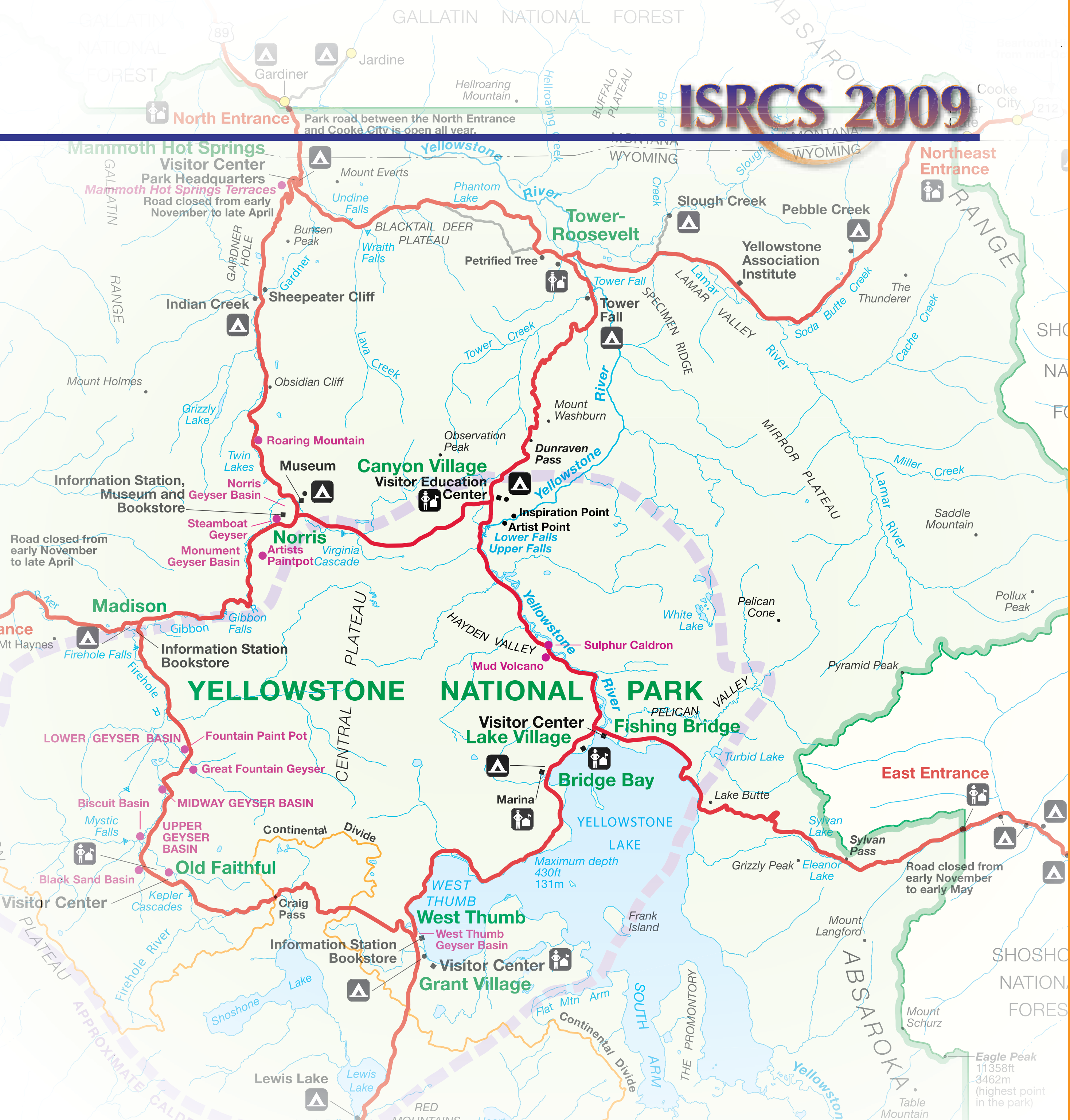
Between stops, a Yellowstone National Park Step-On Tour guide from Xanterra will talk about history, culture, and geography of the park and surrounding areas.

Recommended Items

- Backpack
- Sunscreen
- Chap Stick
- Camera
- Light jacket/sweatshirt
- Water
- Snacks
- Walking Shoes
- Hat
- Sunglasses
- Money (For Souvenirs/ Other Items)

* *Some water and snacks will be provided however, please bring extra water and snacks*




GALLATIN NATIONAL FOREST
GALLATIN NATIONAL FOREST
89
Gardiner
Jardine
Hellroaring Mountain
Hellroaring Creek
BUFFALO PLATEAU
Buffalo
ABSAROKA
Cooke City
Silver Gate
212
North Entrance
Park road between the North Entrance and Cooke City is open all year.
MONTANA
WYOMING
Mammoth Hot Springs
Visitor Center
Park Headquarters
Mammoth Hot Springs Terraces
Road closed from early November to late April
GALLATIN
Mount Everts
Yellowstone
River
Undine Falls
Phantom Lake
Creek
Slough Creek
Slough Creek
Pebble Creek
Northeast Entrance
RANGE
Bunsen Peak
BLACKTAIL DEER PLATEAU
Wraith Falls
Tower-Roosevelt
Petrified Tree
GARDNER HOLE
Gardner
Yellowstone Association Institute
Lamar
LAMAR
VALLEY
The Thunderer
Soda Butte Creek
Tower Fall
Tower Fall
SPECIMEN RIDGE
RANGE
Indian Creek
Sheepeater Cliff
Tower Creek
Lava Creek
River
Cache Creek
SHO
NA
FO
Mount Holmes
Obsidian Cliff
Grizzly Lake
Mount Washburn
MIRROR PLATEAU
Roaring Mountain
Twin Lakes
Observation Peak
Dunraven Pass
Miller Creek
Lamar River
Museum
Canyon Village
Visitor Education Center
Yellowstone
Information Station, Museum and Bookstore
Norris Geyser Basin
Inspiration Point
Artist Point
Lower Falls
Upper Falls
Saddle Mountain
Steamboat Geyser
Norris
Road closed from early November to late April
Monument Geyser Basin
Artists Paintpot
Virginia Cascade
Madison
Gibbon Falls
Gibbon River
White Lake
Pelican Cone
Pollux Peak
ance
Mt Haynes
Firehole Falls
Information Station Bookstore
PLATEAU
HAYDEN VALLEY
Yellowstone
Sulphur Caldron
Mud Volcano
Pyramid Peak
Firehole River
YELLOWSTONE NATIONAL PARK
River
VALLEY
PELICAN
Visitor Center
Fishing Bridge
Lake Village
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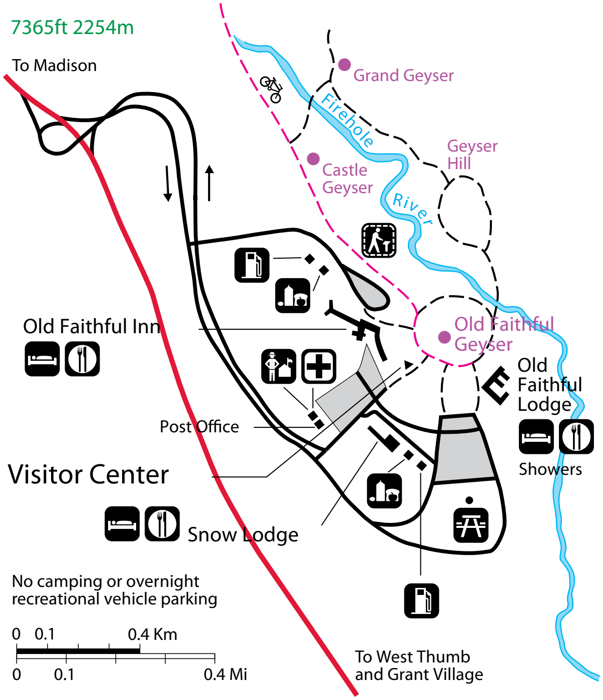
Fountain Paint Pot
Great Fountain Geyser
CENTRAL
Turbid Lake
East Entrance
Bridge Bay
Biscuit Basin
Marina
MIDWAY GEYSER BASIN
Lake Butte
Mystic Falls
UPPER GEYSER BASIN
Continental Divide
YELLOWSTONE LAKE
Sylvan Lake
Sylvan Pass
Old Faithful
Black Sand Basin
Maximum depth 430ft 131m
Grizzly Peak
Eleanor Lake
Road closed from early November to early May
Visitor Center
Kepler Cascades
WEST THUMB
Craig Pass
West Thumb
PLATEAU
Frank Island
Mount Langford
West Thumb Geyser Basin
Information Station Bookstore
Visitor Center
Grant Village
SHOSHO NATION FORES
Firehole River
Lake
Shoshone
Flat Mtn Arm
SOUTH ARM
THE PROMONTORY
ABSAROKA
Mount Schurz
APPROXIMATE CALD
Continental Divide
Eagle Peak 11358ft 3462m (highest point in the park)
Lewis Lake
Lewis Lake
Yellowstone
RED MOUNTAINS
Table Mountain

Yellowstone Maps

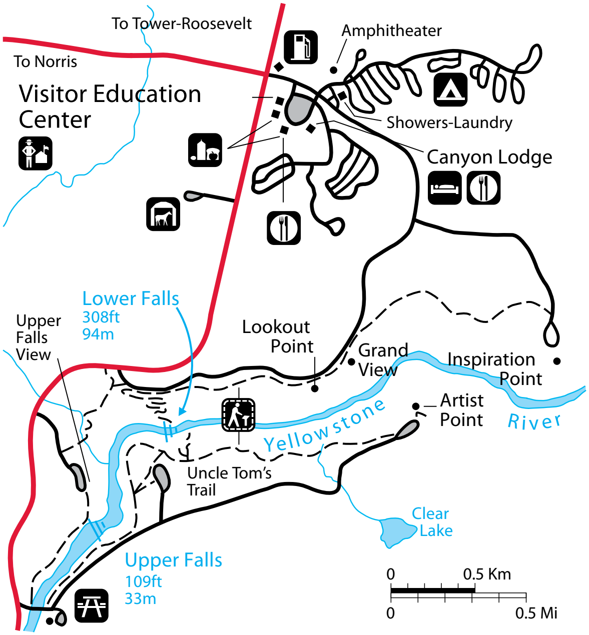
Old Faithful

7365ft 2254m



Canyon Village

7734ft 2357m



Ranger station

Campground

Lodging

Food service

Picnic area

Store

Gas station (some have auto repair)

Self-guiding trail – – – –

Horse rental

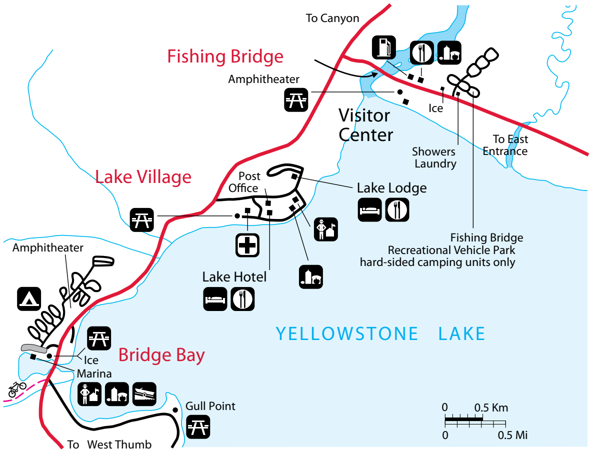
Boat launch

Speed Limit:
45 mph unless otherwise posted. Please drive slowly and cautiously to protect yourself and wildlife.

Nort h

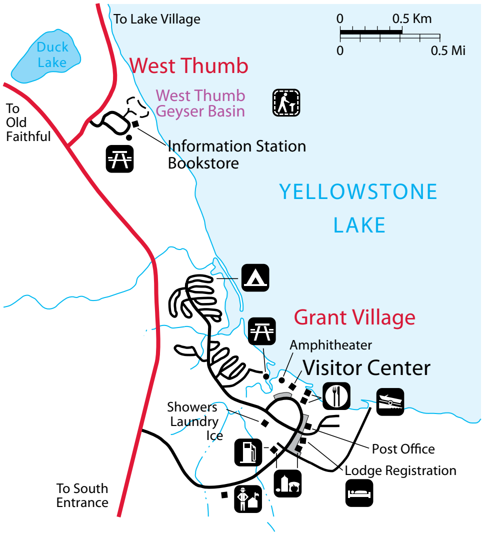
Fishing Bridge, Lake Village and Bridge Bay

7784ft 2373m



West Thumb and Grant Village

7733ft 2357m



Local Information

About Idaho Falls

While retaining its small-town charm, Idaho Falls boasts some of the most beautiful scenery in the West. With an abundance of outdoor recreational opportunities and cultural events at their fingertips, citizens of Idaho Falls are proud to have been ranked 8th in the nation for “hottest small city to live” by Inc. Magazine.

While largely agricultural, Idaho Falls has, among its many highlights, a booming economy with high job-growth rate and the 3rd lowest unemployment rate in the nation. Idaho Falls is the second largest city in Idaho, with a population of 52,730 and an area population of about 125,000. Idaho Falls truly is a great place to live, work, and visit.

Idaho Falls Facilities

A *Engineering Research Office Building*

B *Willow Creek Building*

C *University Place*

D *DOE North*

E *DOE South*

F *INL Research Center*

G *Technical Support Building & Annex*

H *INL Supercomputer Center*

I *Lindsay Building*

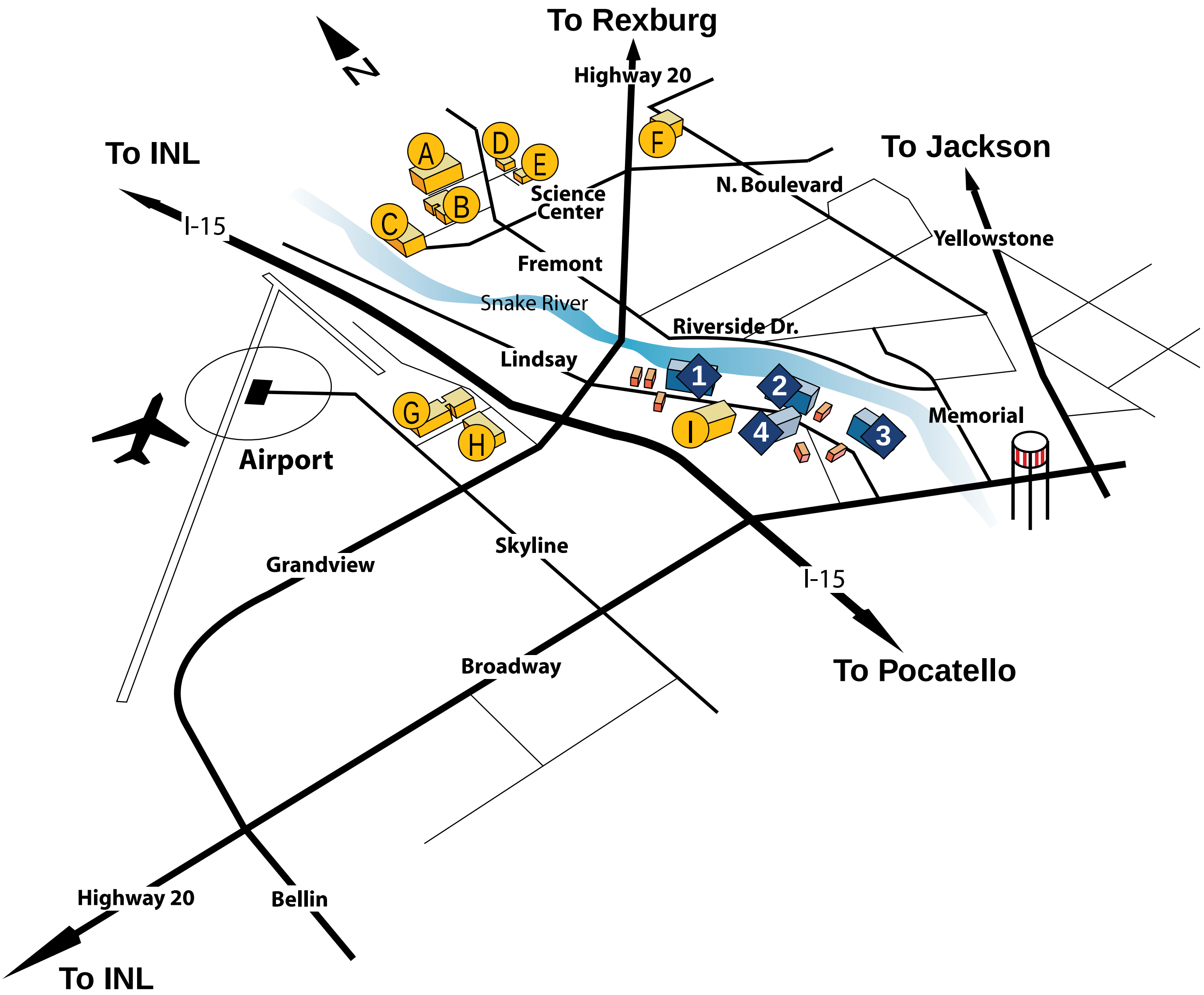
Hotels/Inns

1 *Best Western*

2 *Shilo Inn*

3 *Hilton Garden*

4 *Ameritel Inn*


To Rexburg
Highway 20
N
To INL
I-15
A
D
E
F
B
C
Science Center
N. Boulevard
To Jackson
Yellowstone
Fremont
Snake River
Riverside Dr.
Lindsay
1
2
3
4
G
H
I
Memorial
Airport
Grandview
Skyline
I-15
To Pocatello
Broadway
Highway 20
Bellin
To INL

Local Information - *Continued*

Local Attractions

Museum of Idaho

General Admission- $6
200 N Eastern Ave. (208) 522-1400
Open Mon-Tues 9am-8pm~ Wed-Sat 9am –5pm

Tautphaus Park Zoo

2725 Carnival Way
Idaho Falls, ID
(208) 612-8552
Adults $4, Children $2

Local Golf Courses:

Pinecrest (208) 612-8485
Sage Lakes (208) 612-8115
Sand Creek (208) 612-8535

10-50 Miles Away

Heise Hot Springs

5116 E. Heise Rd.
Ririe, ID 83443
(208) 538-7312
Adults, $6; Children under 11, $3

Yellowstone Bear World

Located 5 Miles
South of Rexburg, Idaho
on U.S. Hwy 20
(208) 359-9968
Adults: $13.95

Hell's Half Acre National Landmark

I-15 between Blackfoot and Idaho Falls

Teton Flood Museum

51 N. Center Rexburg, ID $2

50-100 Miles Away

Yellowstone National Park

Visitor's Center
Yellowstone National Park, WY 82190
(307) 344-7381

Lava Hot Springs Resort

430 E. Main St.
Lava Hot Springs, ID 83246
Phone: (800) 423-8597

Mesa Falls

In Targhee National Forest
Highway 47
Ashton, ID 83420
(208) 652-7442
Fees: $5 per car
Guided tours available

Harriman State Park

Highway 20
Island Park, ID 83429
(208) 558-7368
Fees: $4 per vehicle
Trails, hiking, fly-fishing

Craters of the Moon National Monument

Highway 20 Arco, ID 83213 (208) 527-3257

Grand Teton National Park

Northwestern Wyoming (307) 739-3300

For more information on area attractions visit: Visitors Information at www.inl.gov

Restaraunts within walking distance of the Shilo Inn and Ameritel Inn

Whitewater Grill
355 River Parkway (208) 523-3355

Applebee's Bar and Gill
635 N Utah Ave (208) 528-8985

Rutabaga's
415 River Parkway (208) 529-3990

Outback Steakhouse
970 Lindsay Boulevard (208) 523-9301

The Snakebite
401 Park Ave. (208) 525-2522

Thai House
366 Shoup Ave. (208) 529-2754

Jakers
851 Lindsay Boulevard (208) 524-5240

Brownstone Pub and Brewery
455 River Parkway (208) 535-0310

Chili's Grill and Bar
620 N Utah Ave. (208) 552-2577

Sandpiper Steak and Seafood House
750 Lindsay Boulevard (208) 524-3344

Wasabi Japanese Food & Sushi Bar
355 River Parkway (208) 523-3355

Pachanga's Mexican Restaurant
552 N Capital Ave
Idaho Falls, ID 83402-3555
(208) 522-1976

Community Events August 12-15, 2009

Aug 12, 2009

Alive After Five *When: Aug 12 Time: 5:00pm to 7:00pm Where: Civitan Plaza Park, Corner of Park Ave and B Street in Historic Downtown Idaho Falls*

Aug 13, 2009

Cycles of Sam Exhibit *When: Aug 07 to Oct 31 Time: 11:00am to 5:00pm Where: The Art Museum of Eastern Idaho*

Aug 15, 2009

Idaho Falls Farmers' Market *When: Aug 15 Time: 9:00am to 1:00pm Where: 501 West Broadway, next to the river in the KeyBank parking lot - Downtown Idaho Falls*

"Caves" at Discovery Day *When: Aug 15 Time: 11:00am to 3:00pm Where: Museum of Idaho, 200 N. Eastern Ave., Idaho Falls, ID*

Idaho Falls Artisans Market *When: Aug 15 Time: 9:00am to 1:00pm Where: Corner of Memorial & Broadway, Idaho Falls*

Swan valley art in the park *When: Aug 15 to Aug 16 Time: 10:00am to 6:00pm Where: swan valley park "across the street from the famous square ice cream cones"*

Notes

Notes

ISRCS 2009