Systems Integration and Visualization of Yellowstone (SIVY)

A collaborative project funded by NASA's Earth Science Enterprise
A project of the Research Education Applications Solutions Network (REASoN)

Project members: Dr Fred Watson[1] (PI), Dr Bob Garrott[2], Dr PJ White[3], Dr Susan Alexander[1]
[1]California State University Monterey Bay (CSUMB) [2]Montana State University Bozeman (MSU) [3]National Parks Service, Yellowstone (NPS)

Verification and Validation (V & V) Report

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A PUBLICLY AVAILABLE DOCUMENT

1. Introduction

This Verification and Validation report is intended to provide evidence to NASA that the products produced by the SIVY Project are being used by National Park Service. In turn, this is evidence of the utility of NASA R&D in general. The V&V report is the second of three reports required of projects funded through NASA's Applied Science Program (ASP). ASP uses these documents to report to Congress on its annual performance in terms of societal benefits derived from the funds allocated to the program. V&V reports should describe project products, and document how they were delivered and used by partner agencies – in this case, NPS.

The SIVY project in general seeks to research and develop new uses of NASA technology within NPS at Yellowstone National Park. We provide representative (non-exhaustive) evidence of such use in four areas:

Example 1: Collaborative development of a major book: *Large Mammal Ecology in Central Yellowstone*.
Example 2: Collaboration with NPS staff on journal papers.
Example 3: Snowpack model nowcasts for trans-boundary bison management
Example 4: Interactive Virtual-Reality Kiosk in NPS Visitor Education Center

2. Background: Project Abstract (from Project Plan)

2.1. Purpose and Scope (excerpt)

The Systems Integration and Visualization of Yellowstone (SIVY) project will describe an integrated ecology of large mammalian wildlife systems in Yellowstone National Park (YNP). This will be achieved in a number of ways, including:

- Baseline scientific research into remote sensing and modeling of landscape dynamics and wildlife interactions
- Development of unique visualization tools based on a combination of computer animation and film footage
- Deployment of visualizations for use in Visitor Education Center (VEC) kiosks and by Park managers
- Development and use of educational modules emphasizing an integration of ecological viewpoints at the landscape scale

The project will result in increased understanding of Earth system dynamics, particularly with respect to large wildlife-dominated ecosystems. Its advances will encompass scientists, resource managers, and the

general public. Its results will demonstrate new uses for NASA EOS data. It will allow more informed decision-making by Park managers and the general public.

2.2. Project Goal & Objectives (excerpt)

Specific project objectives include:

- Deployment of interactive visualization products in YNP VECs and by YNP staff at Technology Readiness Level 7 by 30th June 2007
- Publication of a series of Journal Papers on snowpack modeling, remote sensing, integration through visualization, and product impacts (various submission dates set)
- Publication and use of 100-level university curriculum synthesizing the above (by 31st December 2005)
- Bundling of data (31st December 2005) and transfer of data and visualizations to ORNL DAAC (by 30th June 2007)

3. Documentation of NPS-use of project results

3.1. Example Project Result 1: Collaborative development of a major book: *Large Mammal Ecology in Central Yellowstone*.

3.1.1. Description

We have secured a contract with Elsevier to produce a book that syntheses the work of our broader collaboration, and that will become a major contribution to the scientific foundation of wildlife management in Yellowstone (see **Table 1**, below). The book's editors are Garrott, White, and Watson – three of the four Co-Investigators in our NASA-funded SIVY project. The book includes 40 co-authors and 10 of these are from the National Park Service. Eleven chapters* are senior-authored by NPS staff; nineteen by MSU; and nine by CSUMB staff.

* Chapters include separate introductions and conclusions to the 5 major parts of the book.

3.1.2. Delivery / demonstration / use narrative

A number of the wildlife chapters in the core of the book rely heavily on spatial data provided by SIVY. For the purpose, SIVY has delivered NASA-derived landscape analyses and spatial model output to the respective NPS and MSU lead-authors for Chapters 8, 11, 12, 14, 15, 18, 21, 27, and 28. These deliveries have occurred electronically every month or so from August 2006 to August 2007. The respective lead-authors have used the supplied spatial data as inputs to statistical wildlife analyses described in their chapters. Drafts for a number of chapters are now with the editors for review; and the entire book is due to the publishers by the end of 2007.

Table 1. Book in preparation under contract to Elsevier "Large Mammal Ecology in Central Yellowstone". The matrix of authors and chapters illustrates how the spatial-data chapters being lead by CSUMB authors at the start of the book are a key foundation for the wildlife ecology and management chapters being lead by MSU and NPS authors in the core of the book.

⊗ = Lead author		MSU	MSU	MSU	MSU	MSU	MSU	MSU	MSU	MSU	MSU / U. Minnesota	MSU / WY Game & Fish	MSU / CO Wildlife	MSU / MT Fish, Wild., & Parks	MSU / MT Fish, Wild., & Parks	NPS	NPS	NPS	NPS	NPS	NPS	NPS	NPS	NPS	NPS	CSUMB	CSUMB	CSUMB	CSUMB	CSUMB	CSUMB	CSUMB	CSUMB	CSUMB	UCSC	U. Wisconsin, Madison	MT Fish, Wild., & Parks	MT Fish, Wild., & Parks	U. Tromso, Norway	
Section	**Chap**	Garrott	Gower	Becker	Jaffe	Borkowski	Rotella	Cherry	Greenwood	Meredith	Berardinelli	Bruggeman	Bjornlie	Bergman	Messer	Fuller	White	Wallen	Smith	Plumb	Olliff	Geremia	Stahler	Davis	Reinhart	McClure	Watson	Alexander	Moore	Newman	Anderson	Cornish	Detka	Thein	Masek	Lockwood	Kramer	Mertens	Hamlin	Aune	Yoccoz	**Chapter title**
Introduction	1	⊗																																							Integrated science in the central Yellowstone ecosystem
Landscape & Climate	Intro																									⊗															
Landscape & Climate	2																									X			⊗												The central Yellowstone landscape: geology, terrain, vegetation
Landscape & Climate	3																									⊗			X												Climate: good years, bad years, and long-term change
Landscape & Climate	4																									⊗	X														Effects of Yellowstone's unique geothermal landscape on snow
Landscape & Climate	5																									⊗	X	X			X	X		X		X					Effects of wind, terrain, and vegetation on snowpack
Landscape & Climate	6																									⊗	X		X		X		X								Modeling snowpack dynamics
Landscape & Climate	7																									X			X	X	X		⊗		X						Vegetation phenology - evaluating the "green wave?"
Landscape & Climate	Synth																									⊗															
Ungulates pre-wolf	Intro																⊗																								
Ungulates pre-wolf	8	X						X		X					⊗		X									X															Elk spatial dynamics and resource use patterns: adaptation to
Ungulates pre-wolf	9	X				X					X						⊗																				X				Diet composition and nutrition of elk during winter
Ungulates pre-wolf	10	⊗					X										X																							Elk population dynamics before wolves: A bottom-up system
Ungulates pre-wolf	11	X										⊗					X									X														Bison range expansion
Ungulates pre-wolf	12								⊗								X	X				X																		Recovery of Yellowstone's bison: a century of population dynam
Ungulates pre-wolf	13	X														X	X	⊗				X																	X	Birth, death, and survival of bison in central Yellowstone
Ungulates pre-wolf	Synth																⊗																								
Wolves	Intro	⊗																																							
Wolves	14			X															⊗				X																		Recolonization dynamics of a new wolf population
Wolves	15	X	X	X	X									⊗			X																								Wolf movement patterns in relation to prey and kill sites
Wolves	16	X		⊗	X									X			X									?					?									Wolf prey selection in an elk-bison system: choice or circumsta
Wolves	17	X		⊗	X	X								X			X																								Factors driving wolf predation rates: predictably variable?
Wolves	Synth	⊗																																						
Wolf / ungulate	Intro	⊗																																						
Wolf / ungulate	18	X				X											⊗							X	X	X															Spatial responses of elk to winter wolf predation risk
Wolf / ungulate	19	X	⊗					X									X									?					?									X	Variation in elk grouping strategies: finding the balance in a vul
Wolf / ungulate	20	X	⊗					X									X																							Alterations in elk winter foraging time: consequences of living i
Wolf / ungulate	21	⊗												X			X									X														Characterizing elk resource selection responses to wolf predati
Wolf / ungulate	22	X				X					X						⊗																					X			Effects of predation risk on the nutrition of elk
Wolf / ungulate	23	⊗					X										X																							Post-wolf elk population dynamics: strong top-down regulation
Wolf / ungulate	24	⊗										X					X																							Interaction, limitation, and regulation in a wolf-elk-bison foodwe
Wolf / ungulate	25	X														X	X																					⊗			Contrasting wolf-ungulates interactions in the Greater Yellowst
Wolf / ungulate	Synth	⊗																																						
Humans / wildlife	Intro																⊗																								
Humans / wildlife	26	X				X											⊗							X	X	X															Wildlife responses to park visitors in winter
Humans / wildlife	27	X										⊗	X				X									X														Bison winter road travel
Humans / wildlife	28	X										⊗					X	X								X														Landscape and snowpack effects on bison travel patterns
Humans / wildlife	Synth																⊗																								
Education & management	29	X															X			X						X	⊗		X			X	X								Communicating ecological knowledge to students and the publ
Education & management	30	X															⊗				X																				Science in National Parks: expectations, limitations, and contri

3.2. Example Project Result 2: Collaboration with NPS staff on journal papers

3.2.1. Description

Journal papers are a key deliverable of the project. Collaborative authorship including NPS authors implies the utility of the research for NPS purposes.

3.2.2. Delivery / demonstration / use narrative

Seven papers relating to the SIVY project and including PI Watson as an author have been published or are in press. Two of these included NPS co-author and co-I P.J. White:

Bruggeman, J.E., Garrott, R.A., White, P.J., Watson, F.G.R., & Wallen, R. (2007) Spatial variability in Yellowstone bison use of a road and travel network.: *Ecological Applications*, 17:1411-1423.

Bruggeman, J.E., Garrott, R.A., Bjornlie, D.D., White, P.J., Watson, F.G.R., & Borkowski, J. (2006) Temporal variability in winter travel patterns of Yellowstone bison: the effects of road grooming. *Ecological Applications*, 16(4):1539-1554.

A further paper is in prep.:

Watson, F.G.R., Cornish, S.S., Garrott, R.A., & White, P.J. (in prep.) Improved estimation of species distribution by simulation of diffusion through heterogeneous environments.

3.3. Example Project Result 3: Snowpack model nowcasts for trans-boundary bison management

3.3.1. Description

The National Park Service uses NASA snowpack modeling to inform their management of bison during controversial trans-boundary migration periods in Yellowstone National Park.

Bison are symbolic of the National Park Service, and the Yellowstone herd is the only herd that has remained intact since pre-historic times. After dwindling to fewer than 50 animals by 1902, NPS has restored the herd to between 2500 and 5000 animals.

Every winter, the deep snow in Yellowstone drives the herd to lower elevations in search of accessible forage. Migration across Park boundaries brings them into conflict with other land use objectives, and under an inter-agency plan, they may be herded into corrals and either sent to slaughter or released once the snowpack subsides.

The Langur snowpack model provides information on past and present snowpack distribution in relation to bison migratory routes. It allows managers to evaluate current snowpack conditions to see if the ablation of the snowpack over key foraging areas has reached the point when, in previous years, bison began moving back toward them. The model was developed by a NASA-funded collaboration led by Dr Fred Watson including California State University Monterey Bay, Montana State University, and the National Park Service.

Landsat ETM+ imagery is used as an input to the snowpack model. Visual bands are used to quantify percent forest cover, while the thermal band is used to map geothermal heat and its subsequent influence on the snowpack. The ETM+ sensor also reveals snow cover information that is used as one of the sources of validation data for the model.

The research and development of this specific modeling application was requested by the Park Service for the 2003-4 winter, when it was tested in proof-of-concept form. An improved model was then used by managers in the 2005-6 winter. Improvements for the 2006-7 winter are focusing on an automated online version, further increasing the transparency, archival, and reliability of the information used.

This work is one of several new developments of NASA technology to support the mission of NPS at Yellowstone. It was featured in a NASA press release picked up by international media in at least 6 countries. See: http://www.nasa.gov/centers/goddard/news/topstory/2006/yellowstone_bison.html

3.3.2. Delivery / demonstration / use narrative

The 2005-6 season resulted in the most significant use of this product to date. The snow was deeper than average, and the bison population was at a record high.

During this season, Rick Wallen and Chris Geremia (both with NPS Bison Ecology and Management Team) emailed Fred Watson in mid-winter, requesting the snowpack nowcasts. Watson's team then produced the snowcasts every few days, posted them on the web, and emailed the links to Wallen & Geremia. The products included both 3D visualizations and raw Excel spreadsheets with mean daily snowpack estimates for key foraging areas.

In mid-April, SIVY received word from NPS that the bison had been released (and that they had headed back into the park as predicted), and thus that the nowcasting season was over for another year.

In June 2006, Dr Wallen recalled that Spring's activities in email to an NPS colleague:

> "*…The value of the work was recognized very early as it relates to the relationship of elk and bison ecology, predator prey relationships in the Central interior of the park, and wildlife/ winter recreation issues. … Most recently the Gates report* [a milestone report commissioned by YNP to examine controversial bison issues, ed.] *requested model outputs to help inform his team and for use in their systems model described in their report. In spring of 2004 we used a very preliminary data set* [From the SIVY project, ed.] *to try and estimate snow free area on the Gardiner Basin winter range to inform management about the conditions of the range as we were trying to decide when to release bison from our Stephens Creek holding facility. We subsequently expanded the sampling and validation area to include the whole park so that the model could be used for a wide variety of purposes by the park staff. During the spring of 2006 we ran the updated snow model weekly to provide information to YCR and park management about the snowpack conditions estimated at the time of projection and to inform management about the nature of the melting process as projected for the previous 10 years. The collaboration with CSU scientists is possible because of a grant they have received from NASA to conduct this modeling effort. The final product, when finished, will be a web based snow model for use by Yellowstone staff and scientists studying ecosystem processes in the park vicinity. …I hope this helps better inform you of our collaborative work being done with these valuable partners (Both CSU and NASA). The complexity of our integrated work and the relationship to products that rely on snow model outputs is much larger than this press release describes. The focus here has been to show one example of how this science product, funded by our partnership with NASA, has been used to inform the management decision making process at Yellowstone National Park. There are other examples that we could discuss in subsequent news releases if the interest is there.*"

In 2007, we improved the accessibility of the snowpack nowcast information via a new interactive web interface, and an automated system for running the model:
http://ecoviz.csumb.edu/ynp2/nowcasts/snow_gard/

As it turned out, 2007 had the earliest snowpack meltout in recent years, so there was minimal need for the nowcasts. But every light snow year allows the bison population to grower larger, potentially foreshadowing a big out-migration year to come again soon. We will continue to improve the automation and accessibility to maximize readiness.

3.4. Example Project Result 4: Interactive Virtual-Reality Kiosk in NPS Visitor Education Center

3.4.1. Description

On August-25-2006, Yellowstone National Park opened its newest and largest Visitor Education Center at Canyon Village.

The Visitor Education Center includes an interactive Visualization Kiosk developed by the SIVY project.

The kiosk lets visitors 'fly' through a dynamic visualized landscape incorporating wildlife data, snowpack dynamics, and documentary-style stories on wildlife. It educates visitors about the vast scale of the bison migration at Yellowstone, and the complexities of the landscape through which this migration occurs.

The product renders very large landscapes in full 3D realism populated entirely by `real-world` ETM+ and modeling data on vegetation, geothermals, and snowpack. This is accomplished using the Tarsier environmental modeling software environment, whose development is lead by the SIVY project.

The kiosk implements a novel Interpretive Education technique coined as `The Virtual Interpretive Trail`, whereby the vistor`s `fly-through and watch` experience is intended to be metaphorically familiar with their previous experiences at much smaller scales walking along physical interpretive trails, reading interpretive panels, and watching TV documentaries. It is a unique application of NASA R&D in support of the mission of park management by National Park Service `For the people…`.

3.4.2. Delivery / demonstration / use narrative

The initial physical kiosk remains in use at the Canyon Visitor Education Center in the center of Yellowstone National Park. In summer 2007, we upgraded it to a more-reliable version that doesn't rely on a physically spinning DVD disk, since most of the computer-based exhibits in the VEC had overheating problems.

In early 2007, an online version the kiosk product was developed and picked up by the National Park Service for use in their `Windows into Wonderland` web outreach to primary schools. In this domain, the online kiosk supplements the `Where the Bison Roam` Electronic Field Trip launched in mid-2005 also including some earlier materials from the CSUMB/MSU/NPS collaborative project. In 2006, the EFT was accessed by over 75,000 viewers represented by registered individuals (assuming an average of 18 viewers per registered individual, e.g. per teacher).
Direct link: http://www.windowsintowonderland.org/bison/watershed/index.html
Top-level link: http://www.windowsintowonderland.org/

In Spring 2007, Dr Watson presented the kiosk at the biennial meeting of the George Wright Society, attended by hundreds of National Park units. The presentation resulted in immediate requests for collaboration from other Park units, to which the SIVY project responded with a collaborative proposal submitted to NASA for similar work involving 8 other Park units.

Also in Summer 2007, we have delivered near-final drafts of a few additional geothermal visualization products for deployment in NPS's Old Faithful Virtual Visitor Education Center, due to open sometime in late 2007.

We received an unsolicited email from the Chief of Interpretation at Yellowstone, Diane Chalfant, on 1st March 2007:

> *Dear Fred,*
>
> *I realize that I hadn't thanked you for the work that you and your colleagues did on the bison migration DVD for the Yellowstone geoecosystem area of our new Canyon Visitor Education Center. The building opened late last summer to a whirlwind of activity and then was closed again by early October.*[It closes every year for the winter, ed.] *Initial response to the exhibits from the public has been tremendously positive. We will reopen again in the end of May and we look forward to more feedback from our public.*
>
> *The work that you and the team did on this project and on the bison electronic field trip contributed significantly to the public's understanding of the interrelationships between*

Yellowstone's wildlife, its habitats, and climate. ***Hundreds of thousands of visitors annually will benefit from your work.***

We look forward to future collaborations with you and your team.

Sincerely,

Diane M. Chalfant
Chief, Division of Interpretation

4. Conclusion

The above examples illustrate how the SIVY Project is engaged with the NPS mission at Yellowstone on a number of levels. Our journal papers and book development describe fundamental scientific advances involving the use of cutting edge spatial data technology for wildlife management. They establish the general credibility of our work, and contribute to the overall scientific foundation that NPS uses to sets policy. The active web site for snowpack nowcast exemplifies more of a real-time management use of a particular product; and the visitor center kiosk illustrates application at the interpretive and educational ends of the pipeline of scientific information that the project has established.