Integrated Shelter, Clothing and Sleep Systems for Ultralight Hiking in Inclement Conditions

by Ryan Jordan

Technical White Paper
Skill Level: Intermediate to Advanced Lightweight Backpackers

Objective and Scope

My objective with this white paper is to discuss the feasibility of, and various options for, integrating your shelter, clothing, and sleep system for ultralight backpacking in inclement conditions, with special attention paid to mountain travel. Herein, mountain travel is considered as a relative extreme because of greater exposure to winds, freezing temperatures, rain, and snow relative to below the tree line. The information provided herein is to be considered in the context of the "normal 3-season" backpacking season (defined as that period of time between the peak spring snowmelt (e.g., June in the northern Rockies) and the arrival of the first permanent snows of winter (e.g., November in the northern Rockies) that inhibit "boot" travel on trails).

The Need for Integration

Integrating your equipment into a cohesive system requires an understanding of thermoregulation (physiology) and resistance to inclement environmental conditions (weather), topics not discussed herein but highlighted so the reader can seek other sources of information about them. Optimizing the degree of integration results in a system of equipment that minimizes the weight carried in your pack while providing a suitable margin of safety.

System Components

The key components of the system described herein can be subdivided, for ease of understanding, into three major categories:

- Shelter
- Sleep systems
- Clothing

Within these categories (recognizing that you are creating an integrated system in which a piece of equipment from one category can serve functions in other categories), specific functions that must be addressed include:

- Thermoregulation (managing excess heat and preserving warmth)
- Wind protection
- Rain and snow protection

Consequently, we can define a traditional list of possible equipment that might be assigned to each category:

Shelter	overhead shelter (tarp or tent)
	ground stakes and guylines
	shelter poles
	ground cloth
Sleeping	sleeping bag
	sleeping pad
Clothing	insulative clothing
	shell clothing for wind and rain protection
	base layer clothing for moisture management

Since we are most interested in developing an ultralight system that is integrated, we recognize that clothing plays an important role in keeping warm at night, when it is worn in conjunction with a sleeping bag. Thus, herein, we will focus primarily on discussing insulative clothing and secondarily focus on shell clothing, but only to the extent that it can be obviously combined as part of a shelter system (e.g., poncho-tarp).

An Overview of System Function

To understand how to optimize a shelter, clothing, and sleep system, you must distill the functions of your gear into the most basic components.

A minimal shelter is comprised of three key functions:

- Overhead protection from precipitation
- Resistance to boundary layer convective heat loss from the sleeping microclimate (wind chill)
- Structure as provided by poles, guylines, and ground stakes
- Impermeable barrier to ground surface moisture

A minimal sleep system is comprised of three key functions:

- Resistance to conductive heat loss at the ground surface (e.g., sleeping pad)
- Resistance to radiant and convective heat loss (e.g., sleeping bag insulation)
- Resistance to evaporative heat loss (e.g., sleeping bag shell)

Finally, a minimal clothing system is comprised of two key functions (ignoring for now, the function of next to skin moisture management):

- Resistance to radiant and convective heat loss (e.g., insulation)
- Resistance to evaporative heat loss resulting from outside moisture (e.g., wind and precipitation protection)

And so, from this, we can distill the two core functions of the entire system:

- Protection from wind and precipitation (requires wind and/or waterproof gear)
- Protection from cold (requires insulative gear)

Thus, we have built a remarkably simple framework for designing an integrated, ultralight system of shelter, clothing, and sleep systems.

Protection from Wind and Precipitation

Protection from wind and precipitation has different requirements, depending on whether you are hiking (moving and thus, generating heat) or or camping (not moving and thus, losing heat). Traditionally, we can identify several system components that serve the function of wind and precipitation protection:

- Overhead shelter (tents and tarps)
- Bivy sacks
- Sleeping bag shells
- Shell garments (shirts, jackets, and pants)

Protection from Cold

Likewise, we can similarly identify the two system components that serve the primary function of providing resistance to passive heat loss to cold environments:

- Clothing insulation
- Sleeping bag insulation

Analysis of a Traditional Gear List

In order to understand how an ultralight system can be designed and optimized, we must first analyze the components and functions of a traditional lightweight system (ignoring, for now, the evaluation of a traditional "heavyweight" system that might include such items as six-pound tents, three-pound sleeping bags, and two pounds of raingear), shown in the table below. Scores of 0 to 3 have been assigned, where "0" indicates that the component is not very important, and a "3" indicates that the component is very important.

System 1. Traditional Shelter, Sleeping, and Clothing System (Lightweight)

	Protection from Cold	Protection from Wind	Protection from Precipitation	Typical Weight (oz)
SHELTER				
Tent Body	1	3	3	16
Sewn-In Tent Floor	1	1	3	8
Shelter Poles / Support	0	2	2	8
Stakes and Guylines	0	1	0	2
SLEEPING				
Sleeping Bag	3	1	1	32
Sleeping Pad	2	0	0	20
CLOTHING				
Rain Jacket and Pants	1	3	3	24
Fleece Jacket	2	1	0	16
TOTAL	**10**	**12**	**12**	**8.0 lbs**

Lightening the Load Through Component Integration

The following table shows a tarp-based system, where we have (1) replaced the tent body with a tarp (a savings of 4 ounces at the expense of some wind and precipitation protection), (2) replaced the tent floor with a smaller-sized ground cloth (a savings of 4 ounces with little or no loss of significant function), (3) replaced shelter support poles with trekking poles, which both add weight (8 oz), and result in loss of some wind resistance, but are better integrated into part of the overall equipment kit).

System 2. Replace Tent with a Large Tarp

	Protection from Cold	Protection from Wind	Protection from Precipitation	Typical Weight (oz)
SHELTER				
8x10 Silnylon Tarp	0	2	2	14
Ground Cloth	0	0	2	4
Trekking Poles for Support	0	1	1	16
Stakes and Guylines	0	1	0	2
SLEEPING				
Sleeping Bag	3	1	1	32
Sleeping Pad	2	0	0	20
CLOTHING				
Rain Jacket and Pants	1	3	3	24
Fleece Jacket	2	1	0	10
TOTAL	**8**	**9**	**9**	**7.8 lbs**

As can be seen by comparing these two tables, by simply substituting an ultralight (typically, two pounds with body, floor, and poles) tent with a tarp, ground cloth, and trekking poles, we realize very little weight savings (0.2 lbs) while significantly reducing the system's resistance to cold, wind, and precipitation. Consequently, some skill is required to use this system optimally in inclement conditions, as camping with a tarp in foul weather requires that more careful attention be paid to locating a campsite that provides good resistance to wind, rain, and snow. In short, we realize a loss of total system performance that must be compensated for, in part, by an increase in user skill level.

Now, let's try to gain back some performance (and weight reduction) in terms of wind and precipitation protection by (1) replacing a large tarp with a small tarp, and (2) adding a water-resistant breathable (e.g., Epic) bivy sack with a waterproof, silnylon floor, and (3) doubling the number of stakes and guylines to enhance the quality of the tarp pitch.

System 3. Small Tarp with Bivy

	Protection from Cold	Protection from Wind	Protection from Precipitation	Typical Weight (oz)
SHELTER				
5x7 Silnylon Tarp	0	1	1	7
Bivy Sack	1	2	2	12
Trekking Poles for Support	0	1	1	16
Stakes and Guylines	0	2	0	4
SLEEPING				
Sleeping Bag	3	1	1	32
Sleeping Pad	2	0	0	20
CLOTHING				
Rain Jacket and Pants	1	3	3	24
Fleece Jacket	2	1	0	10
TOTAL	**9**	**11**	**8**	**7.8 lbs**

With System 3, we have gained back some cold resistance by adding a bivy sack, increased system wind resistance with the bivy sack and additional stakes/guylines, and lost some precipitation resistance (with a smaller tarp) - but also gained some precipitation resistance by adding the bivy sack. And, although we realize no weight savings, we increase the overall performance, and thus, the performance-to-weight ratio, of System 3 relative to System 2.

Achieving More Significant Weight Reductions: What's Next?

Integrating Your Sleeping Pad Into Your Equipment System. Let's take a look at the sleeping pad. Above, we assumed that the mainstream backpacking community generally does not tolerate foam pads well, so we've assigned a 20 oz weight to our sleeping pad - for example, the full-length inflatable ProLite pad from Cascade Designs. Let's try to integrate our pad with other gear that is not currently doing anything for us in the evenings - for example, our backpack, and/or, the closed cell foam padding that is often found as part of its suspension. Initially, one may want to experiment with using a 3/4 length inflatable in conjunction with their pack below their feet. This can result in a weight savings of approximately 7 ounces at the expense of little or no loss of significant comfort or warmth for most individuals.

Replace Your Mummy Bag with a Top Bag. Consider replacing your full mummy sleeping bag with a zipperless, hoodless top bag, and simply wear your normal warm headwear at night (in the bivy sack, this provides a surprising amount of warmth), and rely on your sleeping pad for insulation from cold ground. The weight savings to be gained by going from a two-pound down mummy bag to a top bag with an equivalent amount of upper-layer loft is approximately 12 ounces.

Integrating Your Sleeping Bag and Clothing Insulation. Relative to fleece, garments with high-loft synthetic insulation such as Polarguard or PrimaLoft provide a higher warmth-to-weight ratio. In addition, because they are shelled and lined with woven fabrics, they offer better water and wind resistance. Worn in the sleeping bag (or better, to minimize loft compression, simply draped over your torso inside your sleeping bag), a high-loft garment boosts the warmth of your sleep system and you can get away with a lighter bag. And so, we can save, for example, about four ounces by selecting a synthetic-filled pullover that is as warm (or warmer) than the fleece jacket we are removing) and reduce our sleeping bag weight by about the same amount. (Note: we are not considering down insulation here because of the inability to use it as an insulating layer while hiking or resting in inclement conditions - down jackets often remain in your pack as dead weight while hiking in inclement weather due to the justifiable fear of the user at getting them wet and rendering them useless).

Integrating Your Shelter and Raingear. Although this step is not one that is going to be taken by the mainstream ultralight community, it offers the ability to save significant weight in your equipment kit, and is a seminal example of integrating gear for inclement conditions. Using a poncho-tarp offers you the ability to completely eliminate the weight of your rain jacket and pants, recognizing of course, that there are limitations to using a poncho in windy and brushy conditions (although most of these are addressed as you gain experience), and pitching your shelter while it's raining can require quite a lot of care and attention if you are to stay dry (again, a skill learned through experience). So, although you may add back about two ounces to replace the 5x7 tarp with a 5x7 poncho-tarp, you are realizing a weight reduction of approximately 24 ounces, to replace your fourteen-ounce rain jacket and ten-ounce rain pants.

Now, let's take a look at the resulting system if we implement these last four changes to our equipment kit:

System 4. Integrating Sleeping Pad with Other Padding, Integrating Sleeping Bag with Insulating Clothing, Replacing Mummy Sleeping Bag with a Top Bag, and Integrating Raingear/Shelter

	Protection from Cold	Protection from Wind	Protection from Precipitation	Typical Weight (oz)
SHELTER				
5x7 Silnylon Poncho-Tarp	0	1	1	9
Bivy Sack	1	2	2	7
Trekking Poles for Support	0	1	1	16
Stakes and Guylines	0	2	0	4
SLEEPING				
Sleeping ("Top") Bag	2	1	1	20
Sleeping Pad	1	0	0	13
CLOTHING				
Poncho (see shelter above)	1	2	2	n/a (incl. above)
Synthetic High-Loft Pullover	3	2	1	10
TOTAL	**8**	**11**	**8**	**4.9 lbs**

With this system, we have realized a substantial weight savings of 3.2 lbs relative to our original system - a 40% reduction! We have lost a small amount of overall warmth (by going to a "top bag" and shorter sleeping pad), but have gained some of it back by replacing our fleece with a high-loft insulating garment. We lose some wind resistance with the poncho, but gain some back with the shelled high-loft garment. And, we lose some precipitation protection with the poncho (while hiking due to lack of below-the-knee and below-the-elbow coverage, and while camping by not being able to wear the poncho while pitching it), but again, we gain some back with the synthetic high-loft garment. I've found that the water resistance provided by the shell of my high-loft pullover buys me plenty of time to allow me to pitch my poncho-tarp in the rain without getting wet. In the short time that I'm exposed to rain, the resulting water that accumulates on the shell simply beads up and/or is easily wiped off (caveat: it's your responsibility to maintain the DWR finish of the shell) before crawling into my sleeping bag.

Product Highlight: The Bozeman Mountain Works Clothing, Shelter, and Sleep System

System 5, illustrated in the Table below, highlights the equivalent pieces of System 4 available as part of the Bozeman Mountain Works integrated shelter, clothing, and sleep system product line, designed from the ground up as a highly integrated system for the serious ultralight backpacker and alpinist.

System 5. Integrated Shelter, Clothing, and Sleep System from Bozeman Mountain Works

	Protection from Cold	Protection from Wind	Protection from Precipitation	Typical Weight (oz)
SHELTER				
5x7 SpinPoncho-Tarp	0	1	1	4.7
Quantum X Bivy Sack	1	2	2	6.5
Stix X1 Trekking Poles (support)	0	1	1	5.5
AirCore 1 Guylines (25 ft)	combined w/stakes	combined w/stakes	combined w/stakes	0.1
12 Hi-Vis Titanium Stakes	0	2	0	2.8
SLEEPING				
Quantum Arc X Top Bag	2	1	1	16.0
ComfortLite(TM) Inflatable Pad	1	0	0	10.0
CLOTHING				
SpinPoncho (see shelter above)	1	2	2	n/a (incl. above)
Cocoon(TM) PrimaLoft Pullover	3	2	1	9.0
TOTAL	**8**	**11**	**8**	**3.4 lbs**

This system uses a torso-sized inflatable pad that weighs 10 oz (coming this winter and to be featured exclusively at BackpackingLight.com), relying on your pack for for knee and foot padding, and on your shoes and/or extra clothing under your head to keep your spine in comfortable alignment. This pad achieves weight savings and further integration beyond a 3/4-length pad, without losing the critical comfort (or insulation) where it matters most - under your shoulders and hips. I do recognize that some users will find such a pad wholly unsuitable and

uncomfortable, and one must recognize the value of sleeping warmly and comfortably, especially on a long, rigorous hike exposed to inclement conditions.

The system also makes use of new ultralight fabrics, including sub-one-ounce-per-square yard silicone-impregnated waterproof fabrics and Pertex Quantum for breathable fabrics in the sleeping bag, clothing, and bivy sack. Guylines are Spectra(R), stakes are titanium, and trekking poles are single piece carbon fiber.

I have included a specific product line here for two reasons. The first is to provide the reader with an understanding of our philosophy and motivation for specifying a product line available to BackpackingLight.com readers. The second is to encourage the ultralight community that there are still significant advances to be made in lightweight backpacking gear in response to the availability of new materials. In coming years, as materials such as Pertex Quantum, rolled carbon fiber tubing, and waterproof spinnaker cloths become more available to home sewists, new cottage industry companies and more choices in this product space will undoubtedly drive design innovation that realizes even higher performance-to-weight ratios of ultralight backpacking gear.

System Performance Comparison

Despite the fact that the numerical ratings given above are highly subjective and designed simply on a relative (not a linear) scale for comparison purposes, one cannot help but evaluate the performance-to-weight ratio of these equipment systems by defining an overall score equal to the sum of the ratings for cold, wind, and precipitation protection, and dividing the result by the weight. The results are shown in the table below.

System	Cold	Wind	Precip	Total Score	Weight (lbs)	Performance Factor (Score / Weight)
1	10	12	12	**34**	8.0	**4.25**
2	8	9	9	**26**	7.8	**3.33**
3	9	11	8	**28**	7.8	**3.59**
4	8	11	8	**27**	4.9	**5.51**
5	8	11	8	**27**	3.4	**7.94**

Conclusion

I hope that this white paper has given you a good foundation for understanding how shelter, clothing, and sleep systems are integrated. Further, I hope you also realize that the scores assigned herein are highly subjective based on my own experiences in using these systems, and in no way represent a standard. In fact, it is highly likely that if another person were to assign their own scores, they would come up with different results. However, I hope to have alleviated some bias by calculating the Performance Factor shown in the previous table, again recognizing that this shouldn't be taken as accurate along a linear scale, but only as a measure of

performance-to-weight ratios of various systems, evaluated by similar criteria. The reader must recognize, from the comparison table presented in the previous section, that the total performance of a system may decrease as weight is reduced, despite the fact that a substantial increase in the system's performance factor may increase as weight is reduced. The ability to gain back those losses in total performance depends in large part on the skill and experience of the user.

Using an ultralight, integrated equipment kit, especially like one of those highlighted in Systems 2-5, require above all else, the ability to use clothing and tarps appropriately in inclement conditions. For systems 4 and 5, which highlight the additional performance-to-weight ratio that can be gained by using a poncho-tarp and top bag, the user should possess an intermediate-to-advanced set of skills and sufficient experience with this gear before performance benefits can be fully realized.

About the Author

Ryan Jordan is the Product Designer for Bozeman Mountain Works, the house brand of Backpacking Light (http://www.backpackinglight.com), where he is the Editor and Publisher. Ryan has a Ph.D. in engineering from Montana State University and remains in Bozeman as an independent consultant to the medical device industry and owner of two companies, Cytergy E-Learning Systems and Beartooth Mountain Press. Ryan is an avid fly fisherman, alpinist, and ultralight backpacker. He has pioneered several long-distance hiking routes in the Greater Yellowstone Ecosystem, and calls "home" his local mountain ranges of the Beartooths, Spanish Peaks, Tetons, and Wind Rivers.

