SHTP 2023 Seminar #2 -Electrical Systems

Planning, Capacity, Charging

Agenda

- Welcome, purpose, and format of meeting - David Herrigel
- Introductions- Registered Entrants and Moderators
- Electrical Systems - theory, best practices, what will break
- Q&A Discussion
- Communications
- Q&A #2
- Wrap up and Feedback

Racer Intros

Brian Boschma / Max Critterdan

All Is Lost - Without Adequate Power

Power Budgeting

Power Systems

- **DC Power Basic Equations**
  - W=V*A
  - A=W/V
  - Amp Hours = Amps * #of Hours -
    OR how much you use * how long you use it

Offshore Power Systems
Basic Considerations

- **Consumption**
  - **How much energy do you need to run the boat?**
- **Storage (Capacity)**
  - **How much battery capacity is available & appropriate?**
- **Power Generation**
  - **How will you generate power to recharge your battery?**
- **Reliability**
  - **Will it all hold together?**
  - **Can you rewire/rebuild/make-it-work at sea?**

Offshore Power Systems
Consumption

- **Consumption**
  - **How much energy do you need?**

- **Energy Budget**
  - **basics are straightforward - how many amps each device you will use in a day multiplied by how many hours (or fractions of hours) you will use it for**
  - **added together gives you how many amp hours you need per 24 hour period**

Electrical Budget Worksheet (Ankle Biter Santa Cruz 27)

1 Calculate your DC Loads:

	Amps	Hours	AH/Day	Comments
Lighting				
Running Lights (LED, bicolor/stern)	0.2	10	2.0	
Masthead Tricolor Light			0.0	
Anchor Light			0.0	
Strobe Light	0.8	10	8.0	actually run these off of 6 volt lantern batteries, not the "house system"
Spreader Lights			0.0	
Cabin Light (small)	1.0	1	1.0	
Cabing Light (big incandescent)			0.0	
Cabing Light (flourescent)			0.0	
Instrument Lights	0.3	10	2.5	compass lights…in fact I probably won't run these
Handheld Spot Light	10.0	0	0.0	
Other			0.0	
Lighting AH			**13.5**	**since strobes run off of 6 volt lantern batteries, should be 5.5**
Galley	Amps	Hours	AH/Day	
Refrigeration			0.0	
Prop Solenoid			0.0	
Other			0.0	
Galley AH			**0.0**	
Electronics	Amps	Hours	AH/Day	
Autopilot	1.8	18	31.5	
VHF (receive)	0.5	1.5	0.8	
VHF (transmit)	5.0	0.5	2.5	
SSB (receive)	1.5	1	1.5	
SSB (transmit)	28.0	0.3	8.4	
SSB Digital controller			0.0	
GPS			0.0	I have 3 handhelds, which run on AA batteries. I'm taking a lot of batteries.
Instruments			0.0	
Weather fax receiver			0.0	
Radar (standby)			0.0	
Radar (transmit)			0.0	
AIS			0.0	??? I don't have a NASA AIS, now, but might get one.
Energy Monitors			0.0	
Stereo			0.0	
Computer (screen off)	1.5		0.0	
Computer (screen on)	2.1	1	2.1	one hour every other day to send/receive e-mail
Computer (serial adapter)	0.5	1	0.5	
Other			0.0	
Electronics AH			**47.3**	**this section is pretty accurate**
Plumbing	Amps	Hours	AH/Day	
Fresh Water Pump	8.0	0	0.0	Calculate using average water consumption.
Bilge Pump(s)	5.0	0	0.0	This should be zero unless the boat leaks.
Other			0.0	
Plumbing AH			**0.0**	
Inverter	Watts	Hrs/day	AH/Day	All values assume inverter efficiency = 85%.
Microwave			0.0	Power factor may mess up this estimate.
Chargers (nicad)			0.0	
Other			0.0	
Inverter AH			**0.0**	
Gross Energy Consumption AH/Day			**60.8**	**actually should be 52.8 since I am using 6v. Lantern batteres on strobes**

2 Alternative Energy Sources

Device	Amps	Hrs/day	AH/day	
fixed Solar, avg	8.4	7	58.8	Two 40 watt and two 30 watt panels, 140 watts total
flexible, avg	0.0	0	0.0	
Water, avg.			0.0	
Contribution of AES AH/Day			**58.8**	

3	Net Energy Consumption, AH/Day	**2.0**	**So I'm going into the red about 2 amp/hours per day if run strobes from "house"**
4	Desired Hours Between Charging	**120**	**five days**
5	Range of Battery Use	**0.35**	For example, from 50-85% state of charge.
6	Recommended Battery Capacity	**28**	
7	Alternator Output, Amps	**30**	**30 amp portable gas generator: Target would be 25% flooded, 40% gel, of capacity.**
8	Charge Efficiency Factor	**0.85**	Gels = 95%, flooded cells = 85%
9	Minimum Minutes to Charge	**23**	**run the generator for 23 minutes every five days** will likely run an electricity deficit during first 4 days, so run generator on day 4 or 5 I plan to use the windvane to steer the first few days, then switch to autopilot.

SOLAR PANEL ARRAY	type	amps	hours	amp/hrs	
	30 watt BP solar panel	1.8			
	40 watt Kyocera solar panel	2.4			
	30 watt BP solar panel	1.8			
	40 watt Kyocera solar panel	2.4			
	Total amperage of array	**8.4**	**7**	**58.8**	This is conservative. Lots of people tell me I'll get more than 7 hours charge a day.

Electrical Budget Worksheet (Hecla - Hammerhead 54)

DC loads calculated for 12-volt system, single-handed, amp-hours per day

	Amps	Hours	AH/Day	
Lighting				
Running Lights LED			0.0	
Masthead Tricolor Light LED	0.3	9	2.7	
Anchor Light LED			0.0	
Strobe Light Xenon	0.8	9	7.2	
Spreader Lights			0.0	
Cabin Light LED	0.3	9	2.7	
Cabing Light (flourescent)	2.0	1	2.0	
Instrument Lights	0.3	9	2.3	
Handheld Spot Light			0.0	
Other			0.0	
Lighting AH			**16.9**	
Galley	Amps	Hours	AH/Day	
Refrigeration	4.0	6	24.0	
Prop Solenoid			0.0	
Other			0.0	
Galley AH			**24.0**	
Electronics	Amps	Hours	AH/Day	
Autopilot	3.0	20	60.0	
VHF (receive)	0.5	24	12.0	
VHF (transmit)	5.0	0.5	2.5	
SSB (receive)	1.5	2	3.0	
SSB (transmit)	28.0	0.5	14.0	
SSB Digital controller	0.2	2	0.4	
GPS chartplotter	1.2	24	28.8	
GPS backup	0.3	24	7.2	
Instruments	1.0	24	24.0	
Radar (standby)	3.0	8	24.0	
Radar (transmit)	4.0	1	4.0	
AIS	0.1	24	2.4	
Energy Monitors	0.0	24	0.5	
Stereo	1.5	10	15.0	
Computer (screen off)			0.0	
Computer (screen on)	2.1	3	6.3	
Computer (serial adapter)			0.0	
Other			0.0	
Electronics AH			**204.1**	
Plumbing	Amps	Hours	AH/Day	
Fresh Water Pump	8.0	0.3	2.4	
Bilge Pump(s)			0.0	This should be zero unless the boat leaks.
Other			0.0	
Plumbing AH			**2.4**	
Inverter	Watts	Hrs/day	AH/Day	Assume inverter efficiency = 90%.
Microwave			0.0	Power factor may mess up this estimate.
Coffee maker; 4 min/mug * 5	600.0	0.3	16.7	
Sandwich grill; 10 min/sandw * :	700.0	0.3	19.4	
				Ex: pasta 2L water to boil = 0.2hr; boil 12
Cook pot	1000.0	1	92.6	min half power = 0.1hr
Chargers (nicad)	50.0	0.5	2.3	
Other			0.0	
Inverter AH			**131.0**	
Gross Energy Consumption AH/Day			**378.3**	

Alternative Energy Sources				
Device	Amps	Hrs/day	AH/day	
Solar, avg	13.2	6	79.2	2 large panels with MPP regulator
Wind, avg	8.0	18	144.0	AIR-X Marine wind turbine
Water, avg.			0.0	
Contribution of AES AH/Day			**223.2**	

Net Energy Consumption, AH/Day	**155.1**	
Desired Hours Between Charging	**24**	
Range of Battery Use	**0.35**	From 50-85% state of charge.
Recommended Battery Capacity	**443**	Installed 2 x 4DA @ 210A-Hr = 420 A-Hr
Alternator Output, Amps	**105**	Target 40% AGM of capacity.
Charge Efficiency Factor	**0.90**	Gels = 95%, flooded cells = 85%
Minimum Minutes to Charge	**99**	Assumes alternator runs at full output.

IDEFIX Power Budget

Idefix – Olson 30 2010,2012 Great Results, Well Planned

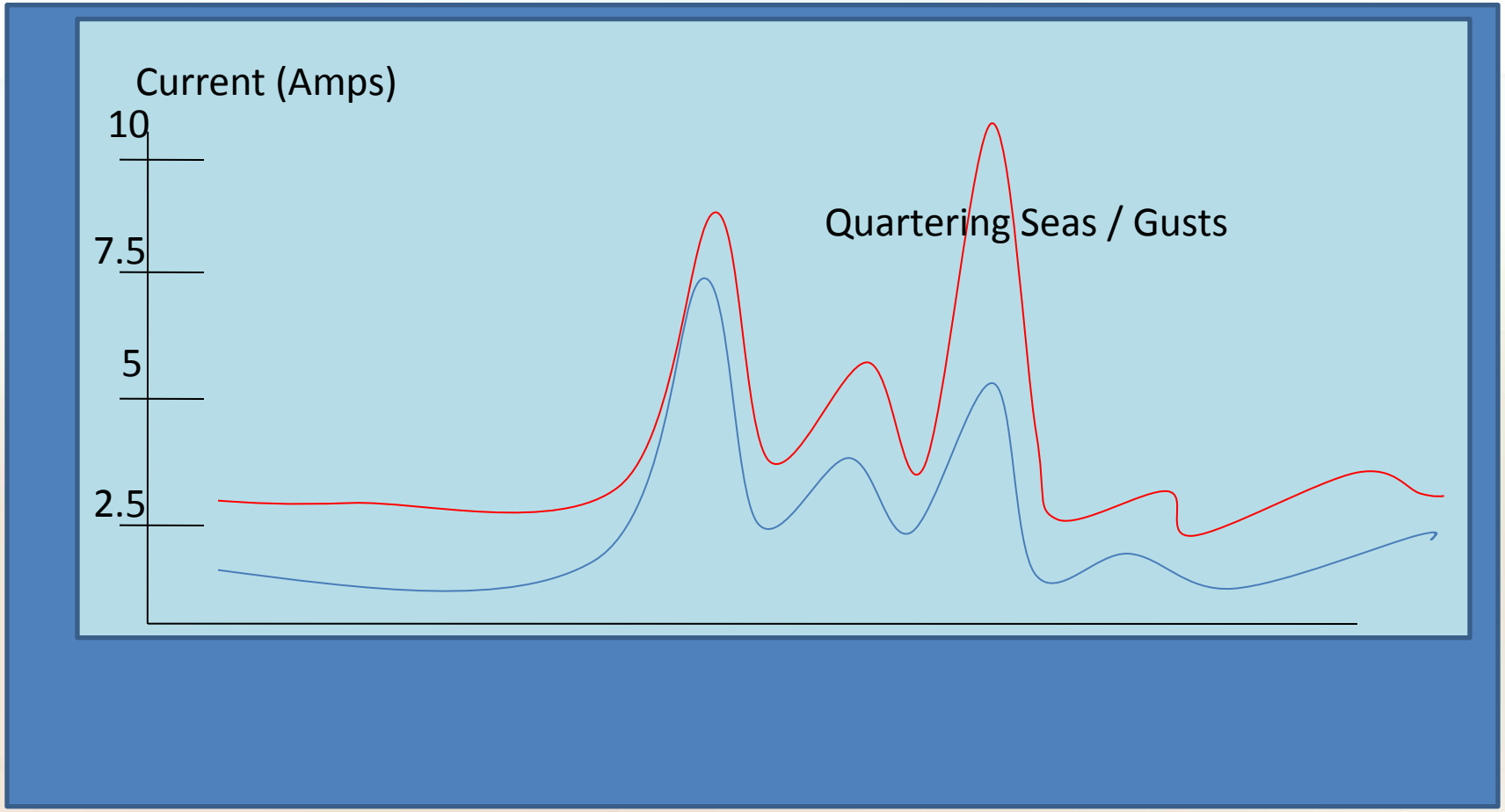
- Solar: 135W hanging off the stern + 40W on the cabintop, wired in parallel.
- Batteries: two 12V 110Ah AGMs wired in parallel with emergency cut-off switches (and fuses added after a short circuit fried all my wiring and detroyed a battery terminal).
  - sized the batteries so to sail half a transpac on battery power alone,
- AP: was two Raymarine X-5s . Power consumption was around 1.5A average, (an estimate).
- Power budget : estimated total energy use at about 56 Ah/day, and generation at about 58 Ah/day.
  - In reality, generation was much higher than this during day.
  - I'd go through about 25-35Ah every night, so use was pretty close to the budget
  - Ran VHF and AIS 24/7.
- On the 2010 SHTP we had sun pretty much the whole way, I had the batteries topped off about mid-day every day
  - On the 2012 SHTP, with overcast the first week or so.
  - My battery monitor had a cumulative error and I wasn't sure where I was on batteries.
  - On day 10 or so it was showing down 50Ah, but voltages were correlating with full charge, so I realized the problem was with the monitor, not the charging system.

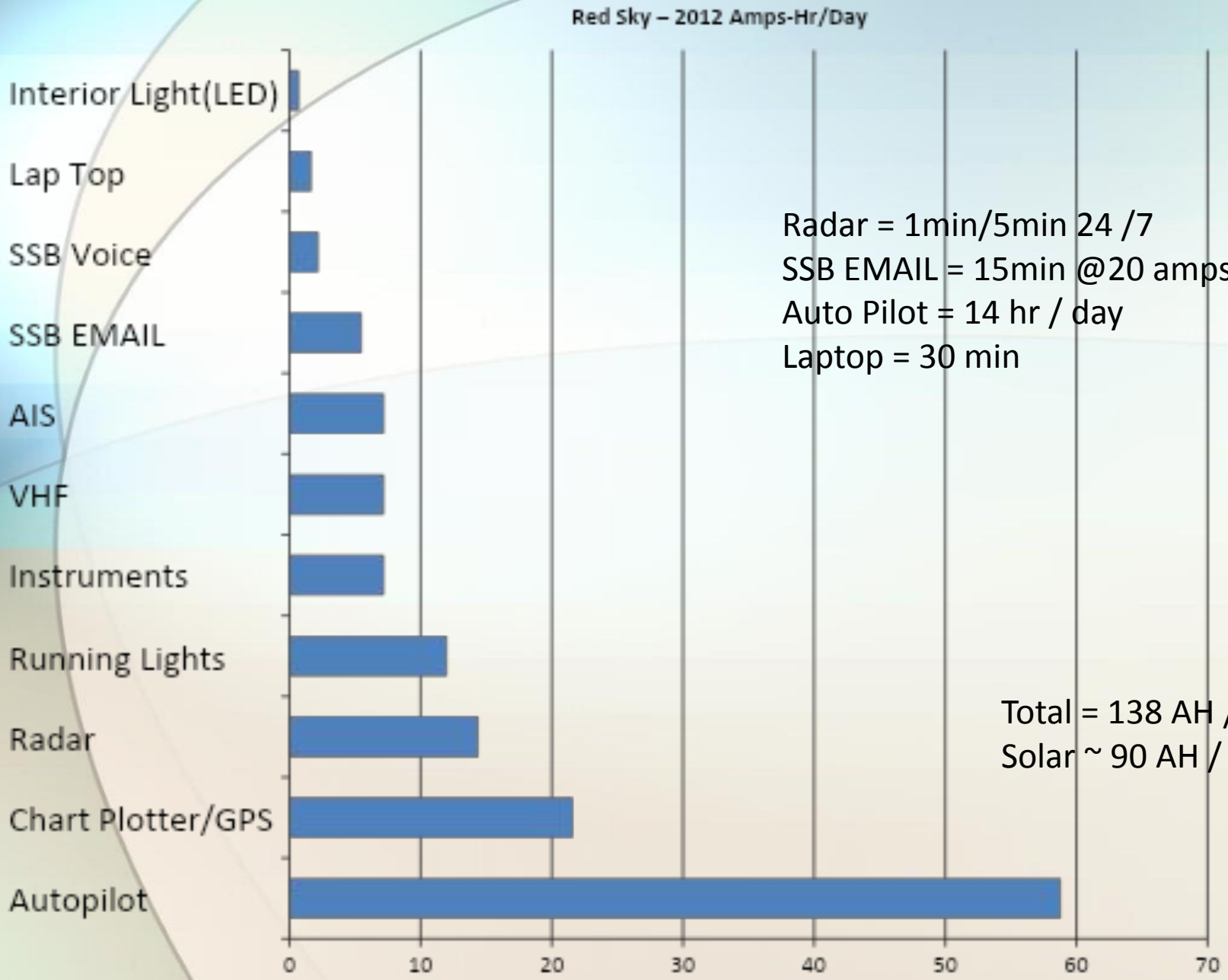
Idefix Budget

electric - TP	7.4W netbook				
	distance	2400			
	speed	7			
	hours	343			
	days	16			
		amps	hours/24		Ah/24
power budget:	AP	1	18		18
	AIS	0.25	10		2.5
	Laptop	0.9	10		9
	VHF	2.08	0.2		0.416
	nav lights	0.5	10		5
	instr	0.32	24		7.68
	music	0.42	4		1.68
	comm	2.5	5		12.5
	Ah/24	56.776			
	Ah total	908.416			
generation	installed P	175			
	Actual P	87.5	0.5	efficient	
	Ah/24	58.3333333333333	8	hours sun	
in-out	**Ah/24**	**1.55733333333334**			
	Ah tot	**24.9173333333334**			
	Instruments	mA			
instr:	ST60 speed	45			
	ST60 wind	65			
	batt mon	10			
	VHF	200			

Typical Current Load for Type 1 Hydraulics and GP Tiller Wands

(there is no such thing as a low power autopilot and
your amperage may vary)





Radar = 1min/5min 24 /7
SSB EMAIL = 15min @20 amps / day
Auto Pilot = 14 hr / day
Laptop = 30 min

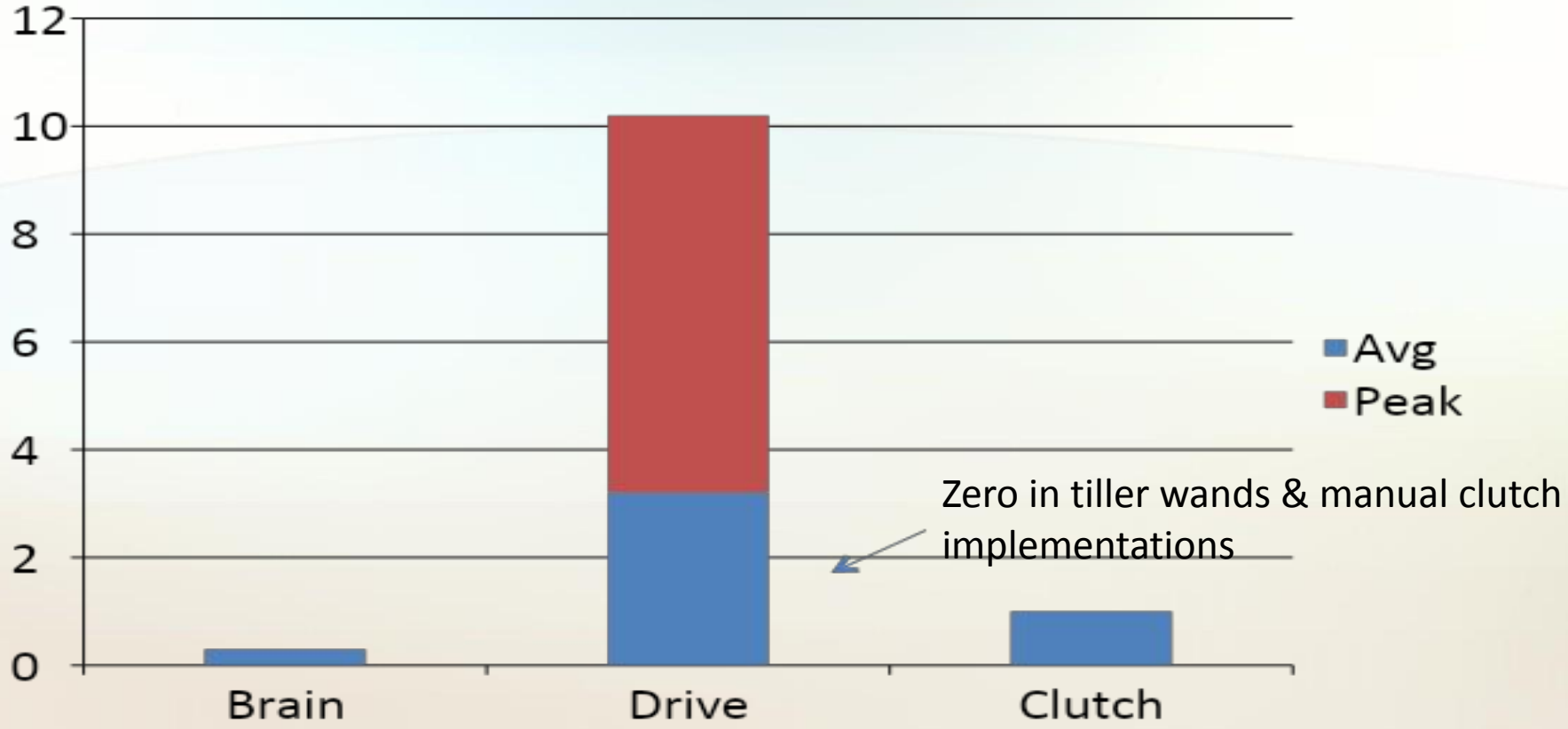
Total = 138 AH / Day
Solar ~ 90 AH / Day

AP Power Use

- Helm load and sea state determine the power usage.
- Ignore the vendor's data, you will likely see several times the current stated in rough conditions.
- Worst case on this playing field is the first 300 to 400 miles: big winds, large seas, little sunlight.
- If you are going pure solar you have to size your battery bank to make it to the sunlight.

Autopilot Current Breakdown

for a below deck system don't ignore clutch power



Offshore Power Systems
Capacity

- **Battery Capacity**
  - **Best understood in terms of Amp hours**
  - **How much capacity you need is a function of how much you consume and how long you want to spend replacing it**
- **Voltage**
  - **12v vs 24v**
  - **12v is the default assumption**

Offshore Power Systems
Battery Monitors

Continuous monitoring of power as it is consumed and replaced

Measures and gives readouts on:

- **Battery Voltage**
- **Power Consumption**
- **Estimated Run Time remaining**
- **current consumption**
- **Battery Temperature**

Offshore Power Systems
Charge Controllers

Alternator	Solar PWM	Solar MPPT	No Controller
Adjust charge profile.	Low cost ~ $25 @ ebay	Cost ~$70++	No Cost
Allows max efficiency of alternator.	Good battery control to keep from over charge.	Best utilization of solar output via “boost” of lower voltages. 30% improvement over PWM (claimed)	Solar connects directly to battery. Use as back up if you suspect a failure.
Alternator needs to have field wire access.	Higher end add battery monitoring	Higher end add battery monitoring	No control on overcharge, but not an issue in the SHTP.

Offshore Power Systems
Battery Type

- **AGM (amalgamated glass matt)**
  - **Secure, tried tested - won't spill, ignite**
  - **Graduated charge acceptance -**
    - **eg as it nears 80% the amount of current that can be absorbed is limited**
  - **relatively inexpensive**
  - **Relatively heavy**

Offshore Power Systems
Battery Type

- **Lithium**
  - **becoming safer with proper Battery Management Systems and charge controllers; also great strides in Li Technology**
  - **Continuous charge acceptance means faster more efficient charging**

  - **Expensive**
  - **Light weight**

Offshore Power Systems
Recharging

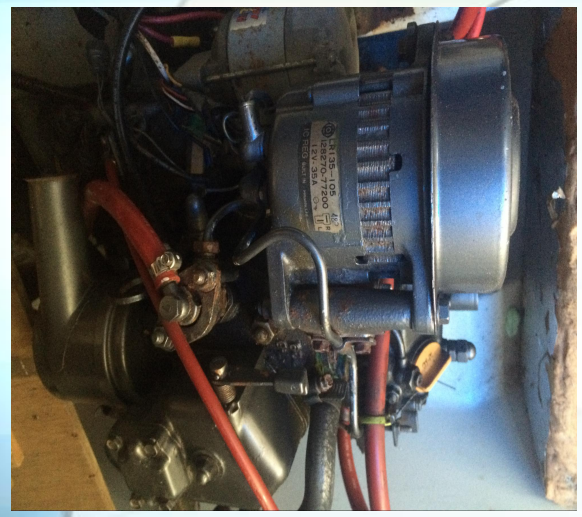
- **Solar**
  - **by far the easiest and simplest System for recharging BUT**
    - **it only works when the sunshines**
    - **limits to the amount of unshaded space on any boat**
    - **do NOT assume that it will work to the rated capacity**
      - **assume 50% of theoretical max and you will be close**

- **You will want a backup**
  - **particularly for the first 3-5 days of the race, typical cloud cover**

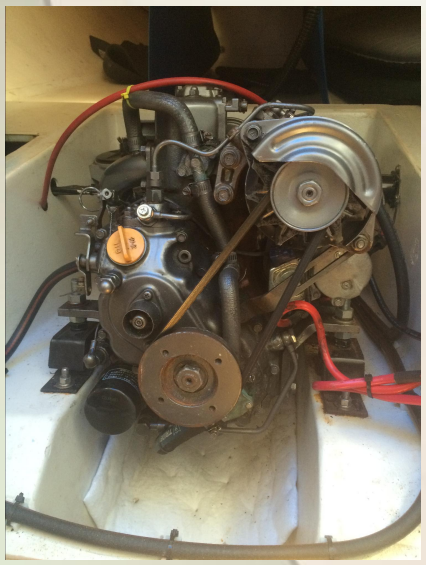
Offshore Power Systems Recharging

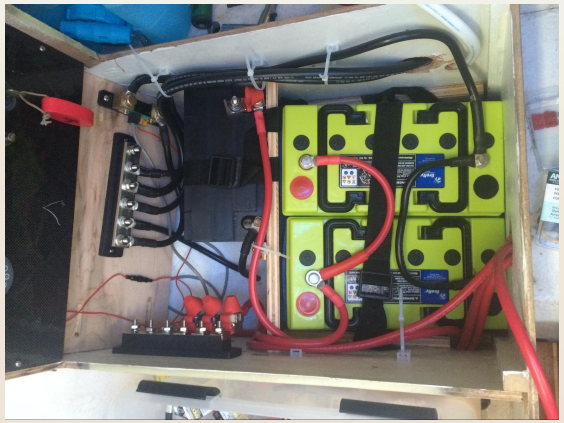
- **Alternator**
  - **for boats with inboards, a default option**
    - **most stock alternators are not built for long term charging**
    - **upgrading to a higher capacity alternator is an option**
      - **be aware of the stresses you will out on brackets and wiring**
      - **your engine does not like low revs and no load**
    - **Best to charge with deeper discharged batteries**
    - **Have a starter battery separate from the house bank**
    - **charge controller /regulator is key to optimizing charging**

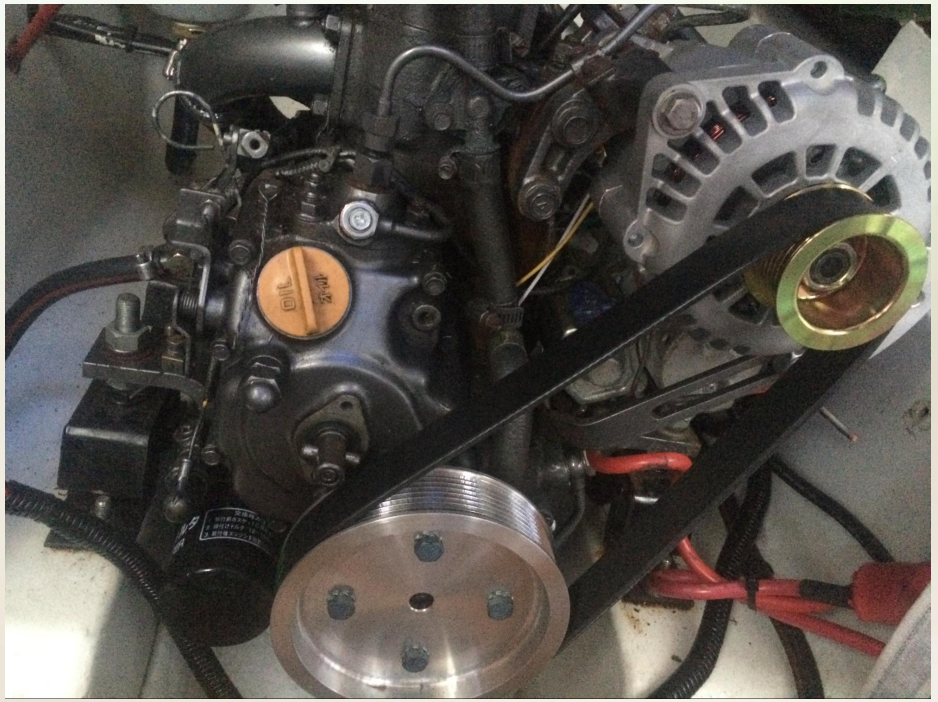
Offshore Power Systems
Recharging
Domino Case Study



- **Old 35A to New 120A with Serpentine Belt & Balmar regulator**
- **100amps Solar on pushpit**
- **2 120Ah Firefly AGM + Starter Battery**



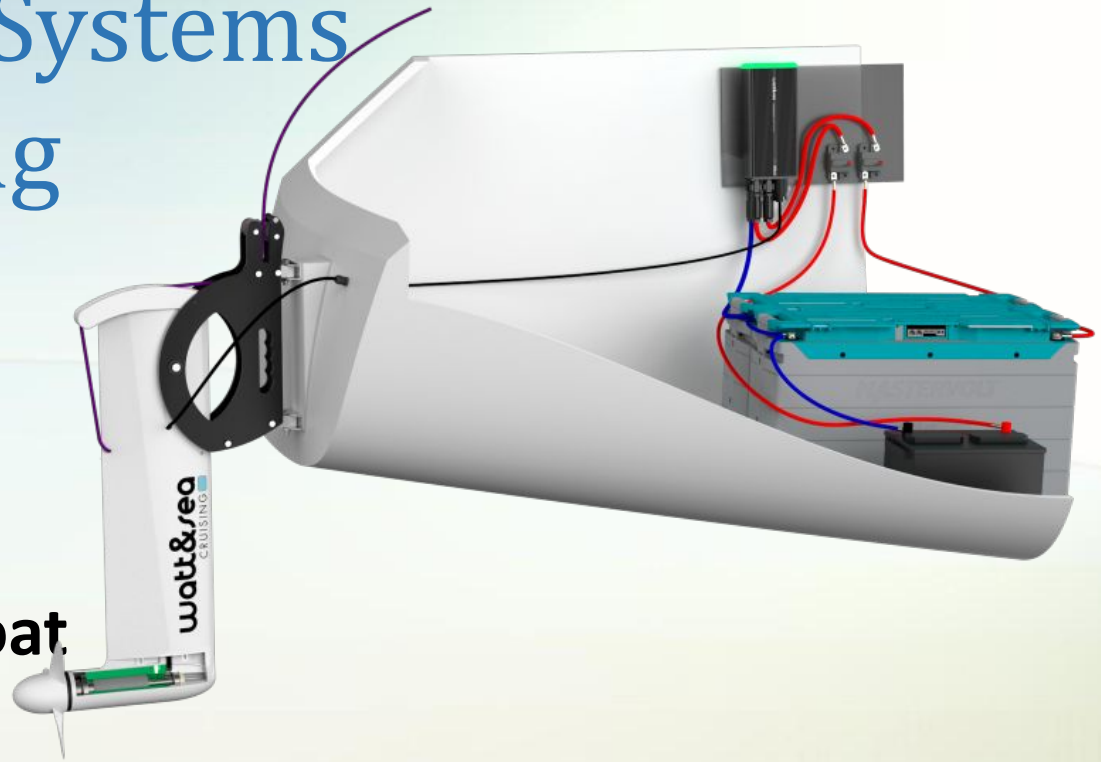




Offshore Power Systems Recharging

- **EFOY Fuel Cells**
  - **Run on liquified methane**
    - **Good Backup for Solar**
    - **somewhat limited in how much charge can be delivered**
    - **Exhaust is water and C02**
      - **can be used in enclosed cabin**
    - **~$4500 new - used for less, available for rent in Europe**

Offshore Power Systems Recharging



- **Hydro Generators**
  - **kick up mount on transom**
    - **Can be tricky depending on boat**
  - **Excellent power to drag ratio**
  - **Generally, as long as the boat is moving it will generate power**
  - **can be fussy to maintain**
    - **seals to the charging component**
  - **$5500-7500 per unit, before installation**

Offshore Power Systems Recharging

- **Small Gas Generators**
  - **Can be a budget backup**
  - **very limited charging capacity**
  - **can be hard to use in a sea-way**
  - **MUST be run in the cockpit**
  - **not marinized**

Offshore Power Systems
Reliability

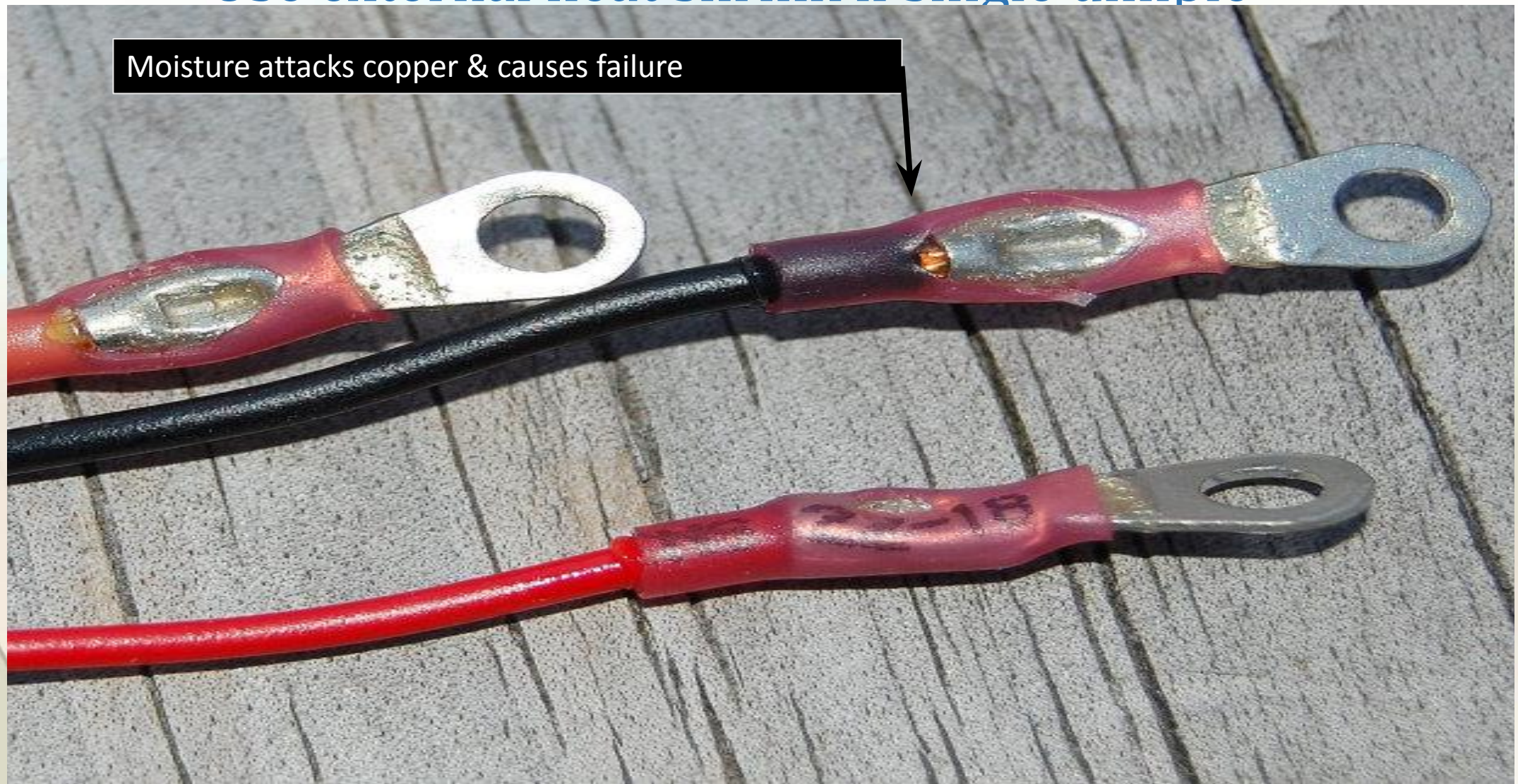
Common Failure Points

- Crimp lugs pulling out.
- Corrosion of wires and connections.
  - Moisture wicking from open ends of wire.
  - Moisture absorption through low quality insulation.
  - Corrosion at screw terminations.
- Mechanical vibration causing crimp & soldered failures.
  - Minimize vibration via tie wraps at points of connection.
  - If you crimp don't solder, if you solder don't crimp (wisdom of local marine electrician).
- Screw terminations with bare wire tend to work lose over time (retighten post install and after use).

Single Dimple Crimp

Splits insulator-Solder expands hole

Use external heat shrink if single dimple



Proper Crimp Results in -

A True Seal Without Solder. cross section of crimp

Copper strands have
Flowed together (same
Phenomena with crimped
Rigging)

Double Crimp Tool

USE QUALITY PARTS

Ancor Tinned Cable

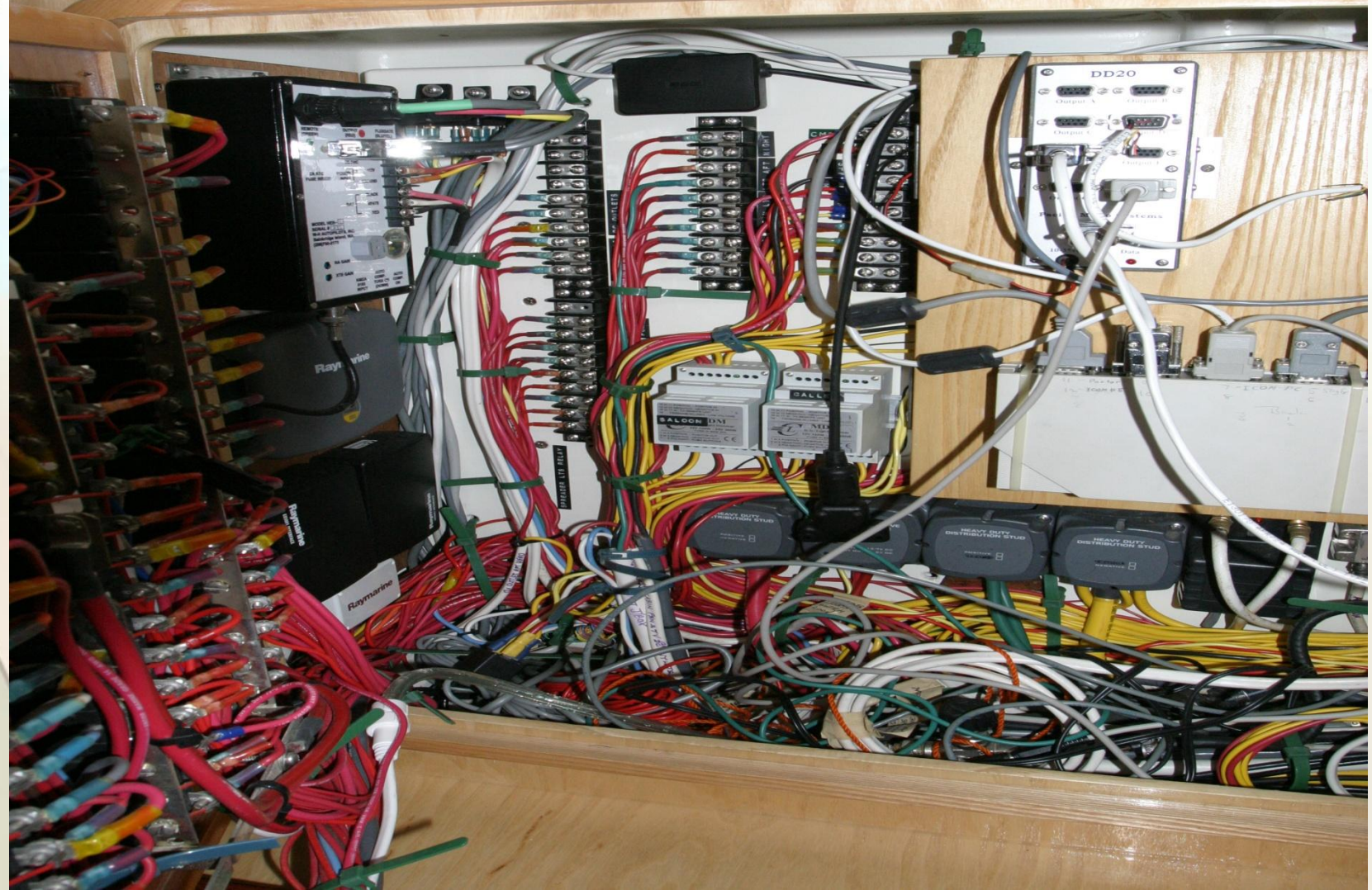
Adhesive Crimps

Double acting ratchet

Proper Tie Wraps to Prevent Wire Vibration

Prevent motion from work hardening connections leading to failure

s/v Cinnabar-Schumacher 52



Ring Terminals all swaged and then sealed with epoxy filled heat shrink.

s/v Cinnabar

Sealed boxes and cable glands for wiring that keep moisture out.

Q&A

Satellite Communications-Trackers

Supported trackers:

Garmin In Reach ,

Garmin In Reach Mini,

or Iridium Go (with several apps)

Note the tracking devices that use the Global Star Satellite (SPOT) system have limited coverage on the route to Hawaii, hence they are not supported.

Race tracking, position reports, and evidence that the racer is still alive are all accomplished using a Garmin Inreach or Iridium GO (satellite tracking transceiver).

Racers will provide their own unit.

Satellite Communications-Voice

The Iridium Go! does support voice calls

Not Always reliably

your cell phone must be on (and still working)

Consider Adding a plain old sat phone as a backup

Can be rented cheaply, or found inexpensively on ebay

Satellite Communications-Data

Iridium Go!

There are other options, but the go is tough to beat as a base data hub

Grib and email often handled through Sailmail

Also many useful apps on tablets and phones

Satellite Communications-Data

Garmin InReach and InReach Mini

interface with phones through blue tooth

functional text message interface

especially with a smartphone

easily set up tracker function

Q&A