- **Status summary**
  - ***Current status of e2e***
    - **Settings for Hanford 2k IFO, 1W**
    - **Field is scalar**
    - **6 suspended optics**
    - **optics has no thickness**
    - **seismic motion is transfer to the table by z -> z transfer function**
    - **local correlation is taken into account by removing the low frequency (<1Hz) component of the ground motion when simulating the 4 suspended mirrors in the corner station.**
    - **A suspended mirror is simulated by a simple pendulum (point object)**
    - **A simple length control**
      - **control matrix (data -> CARM, DARM, PRC, MICH)**
      - **filter (error signal to displacement)**
      - **CARM, DARM, PRC, MICH -> forces on mirrors**
    - **one sensor/actuator per mirror**
    - **no digitization, no whitening/un-whitening**
    - **no ASC**
    - **A simplified PSL/IOO box for the frequency control and laser noise - This has not been used yet.**
  - ***Next release of e2e package (by middle of July)***
    - **Latest control matrix c code for LSC is included**
    - **A package can be easily customized for different IFO and different configuration**
    - **Field can be higher order mode**
      - **no ASC yet, but misalignment effect can be studied**
    - **Thermal noise and shot noise included**
      - **Base line sensitivity curved can be simulated**
    - **Power spectral density can be easily obtained**
    - **Frame interface supported**
      - **A stand alone application will be written which converts the e2e simulation program output (ascii or binary) to frame formatted data file, and vice versa.**

- We discussed pros and cons of adding frame interface directly to the simulation package, and we concluded that this is easier to use.
- "Reality to the model" work can be started
- Basic noise study can be started

- **LIGO I actions**
  - *Goal*
    - Put minimal ingredients in the simulation code
    - Prepare easy-to-use front-end
    - Make e2e useful to help improving the LIGO sensitivity
    - 1 year time scale
  - *Categories*
    - Adding physics
      - Implement new physics by writing C++ code or by combining existing building blocks
      - Mainly done at Caltech.
    - Modeling detector
      - Build a template LIGO model.
      - Site specific implementation of the LIGO model.
      - Test of the model performance
      - Done at Caltech and at each site.
    - Programming issues
      - Code development to make the LIGO model more productive.
      - Mainly done at Caltech.
  - *Adding physics*
    - WFS and 3D mirror (Andrea Vicere)
      - Integrate a simple 3D mirror with stiff wires and perfectly cylindrical shape (primitive exists).
      - This enables the simulation of the coupling of length and angular DOF.
      - Actuation by 4 OSEMs.
    - Servo characterization (Luca Matone)
      - Digitization
      - Whitening and un-whitening
      - Electronic noise
    - Understanding modal model (Biplab Bhawal)
      - Understand how well e2e modal model works for LIGO I, especially when the input test masses are heated up.

- **How many modes are needed to simulate LIGO I cavity ? (now, n+m<=3, do we need to expand to n+m=4?)**
- **Validation of the modal model implementation.**
- **Comparison with the FFT simulation**
- **Comparison with the current LIGO data**

- **Thermal lensing / thermo-elastic effect (Biplab Bhawal)**
  - **How to simulate a hot state of LIGO I ? (minimal model for the small thermal effect)**
  - **Is it enough to use an effect refractive index for ITM to mimic the lens effect ? (different curvatures seen from front and back)**
  - **Validation using FFT and/or Melody**
- **Simple PSL/IOO model (Biplab Bhawal and/or Luca Matone)**
  - **What physics needs to be included ?**
    - ***laser frequency control feedback simulation***
    - ***Proper frequency and amplitude noise in the output field which goes into COC***
    - ***Carrier and sideband noise due to the length fluctuation of the mode cleaner***
    - ***Beam jitter on to the recycling mirror***
      - **Parameterized spectrum based on measurement?**
      - **Simulation by the motion of MMTs**
        - MMT1,MMT2 are small and, MMT3 is large suspension optics
    - ***Radiation pressure***
      - **Is it enough to put just a 1/f^2 spectrum? Proper implementation keeping in mind that it differs in nature from other displacement noises like thermal noise.**
  - **Granularity of PSL/IOO simulation**
    - ***one simple digital filter as the simplest starter model?***
    - ***Triangular mode cleaner cavity for amplitude noise generation***
- **Details of mirrors (Biplab Bhawal)**
  - **Coupling of the mirror vertical motion to the length DOF**
  - **Effect of the curvature of the earth**
  - **Optics imperfections**

- *On reflection by mirrors and transmission through lenses, aberration is implemented perturbatively using mode decomposition matrix.*

- **Thermal noise (Biplab Bhawal)**
  - **Pendulum, Violin and mirror internal thermal noises are included**
    - *All but the resonance frequencies are hard coded.*
    - *One needs to run separate program by Kent and Sam to get values for different temperature, mass and Q.*
  - **Vertical and pitch/yaw thermal noise**
  - **Thermal noise primitives**
    - *For given physical parameters, like temperature, mass, Q, all necessary parameters are calculated internally, no need to run separate programs.*
    - *This makes it easy to put different set of physical values for different mirrors.*
    - *A module which calculates poles and zeros from given physics parameters (temperature, mass, etc)*
    - *One module which corresponds to multiple resonances (equivalent to multiple pole pair digital filters)*
- **More sophisticated 3D mirror (Virginio Sannibale)**
  - **Better simulation of the stack.**
    - *Do we understand the stack well enough ?*
    - *Stack internal mode important ?*
    - *This will be tied with the work getting a "validated" stack transfer function.*
  - **Suspension wire vibration**
  - **Better thermal noise implementation of compound systems**
  - **Mirror shapes different from a perfect cylinder.**
  - **Any of these features important ?**
  - **Integration of MSE**
    - *Completion of API does not take time – 1 week.*
    - *Anything else useful using MSE for LIGO I ?*
- **Other noises**
  - **Radiation pressure, or what else important?**
  - **Non gaussian noises ?**

- ***Modeling detector***
  - **e2eLIGO (Hiro Yamamoto)**
    - **Updated version of Han2k**
    - **Universal package for LHO and LLO, 2k, 4k, FP, Recombined, full LIGO**
    - **No (little) modification of box files needed for different configuration.**
    - **One or two data files will be used to setup the configuration of the simulated detector.**
    - **Ready for multi mode**
      - ***Does not include WFS/3D yet***
      - ***Effect of mirror alignment can be studied***
    - **Thermal noise, shot noise ready to be activated.**
    - **Power Spectral Density can be measured easily (pre configured psd primitives)**
  - **Comparison between e2e prediction with engineering run data**
    - **This will help to understand which elements are important to make e2e closer to reality**
    - **Help to model the seismic motion and stack modeling**
  - **Reality in the simulation**
    - **Ground motion**
      - ***Psd***
      - ***Correlation***
    - **Validation of stack transfer functions**
      - ***Out of 6x6 matrix elements, which are important for the given size of ground motion ?***
      - ***HYTEC model + measurements***
      - ***coupling to z directions from other DOF***
      - ***Use measured mirror motion data for validation***
      - ***Use measured table top motion as inputs to simulation – NOT ENOUGH DATA***
    - **optical and mechanical properties**
      - ***data file for each detector setup***
  - **Update the model for the site and validate by comparing with data**
  - ***Get site specific problems***
  - ***Apply the model to help the commissioning***
- ***Programming issues***
  - **Improvement of environments (Hiro Yamamoto)**

- **Macros, etc**
- **Bundle data type, etc**
- **This can dramatically improve the ease of use.**

- **Save and Load (Hiro Yamamoto)**
  - **Now the simulation must start from the cold state.**
  - **Should be able to store a state and restart from the saved state.**
- **Data Analysis**
  - **Use of CACR for the simulation run. (Ed Maros, Hiro Yamamoto)**
  - **Frame interface (Andrea Vicera)**
- **New optics-field model (Matt Evans)**
  - **Current optics-field model started with a scalar field with no compound cavity in mind, and modal model and compound cavities were added on top of the original framework.**
  - **In order to make it manageable and easy to add new physics, it is time to rewrite the code. Matt has completed a basic work. Integration of this basic work into e2e is a big task.**
- **Improvement of the psd module based on a better algorithm (Andrea Vicere, Hiro Yamamoto)**
- **Support of State Space representation**
- **Add a primitive to simulate the GW signal**
- **Speed up the simulation by adopting various techniques (Matt Evans, Hiro Yamamoto)**
  - **Thread**
  - **Expression templates**
  - **Improvement of code**
- **Improvements of function parser (Hiro Yamamoto)**
  - **“C code” development without compilation**
  - **Optimization of execution stack**
  - **Expand language**
    - ***Goto***
    - ***Better If based on Goto***
    - ***Print***
- **Full LIGO summation code**
  - **One way to speed up the simulation by factor of several.**
- **Frequency domain modeler**

- **GetFreqResponse(vector<real> &freqs, vector<complex> vals);**
- **Multiple time steps**
  - **Small time step for optics, long time step for mechanics, …**
- **Programmer's task**
  - **Profiling**
  - **Memory leak**
  - **Porting code to CACR**
    - ***g++ 2.95.2***
      - **e2e default compiler**
      - **has bug (complex/real => NaN)**
      - **CACR is trying to port 2.95.3**
    - ***KAI compiler***
      - **native complex support, C++ standard compliant**
      - **free license and limited help**
      - **cannot compile**
    - ***HP compiler***
      - **C++ standard compliant**
      - **Linker size limit**
      - **Compiler crashes**
    - ***Interface automating job submission***
  - **Improving parser**
  - **Compile with 64bit architecture**
  - **Save/Load (hiro)**
  - **Expression template**
  - **Thread**
  - **Data visualization**

- ***Schedule***
  - **Actions working with / requesting Detector experts**
    - **ISC/ASC : Nergis Mavalvala**
      - ***Realistic model of LSC***
      - ***A meeting was held on May 30th to discuss the strategy toward implementing a more realistic LSC servo, and the first version of ASC. Minute is http://www.ligo.caltech.edu/~e2e/actions/LSC-ASC-05-30-01.htm.***
        Luca measured necessary data with the help by Nergis
    - **SEI/SUS : Mark Barton and Robert Schofield**
      - ***Seismic motion data, including correlations***
        - **How to model correlation?**
      - ***Stack transfer function***

- **The goal is to obtain a stack transfer function, which is minimal yet good enough to simulate the key feature of the seismic motion.**
- **Some simulation work will be involved to understand various coupling of the DOF.**

- ***Validation of mechanical motion simulation***
  - **Stack transfer function looks OK**
  - **How do we validate the mirror motion ?**
- ***Livingston***

  Seismic motion => Joe Giame
- ***Mark provided us a SUS calculation tool using mathematica.***
- ***Measured mechanical quantities – resonance freq, Q values, etc***

  Hanford : available now

  Livingston : soon

  Mass to mass dependence will not be important

- **COC : Garilynn Billingsley**
  - ***Measured phase map of COC mirrors***
    - **Reflection and transmission phasemap**
    - **How to extrapolate**
    - **Zernike polynomial to Hermite Gaussian**
    - **Orientation of suspended mirror**
    - **By the end of August**
  - ***Optics data – wedge angle, curvature, etc***
- **PSL/IOO : Peter King, Rick Savage, Nergis Mavalvala, Dave Reitze**
  - ***Laser frequency and amplitude noise***
    - **from PSL to IOO and IOO to COC**
  - ***Beam jitter hitting recycling mirror***
  - ***Triangular cavity simulation***

    Do we need alignment control simulated?
- **IOO/COC : Dave Reitze**
  - ***Lumped parameters : intensities, mode matching, length, finess, etc***
  - ***IOO cavity parameters provided (06/05/01)***

    http://www.ligo.caltech.edu/~e2e/actions/IOO-DavidReize.pdf
  - ***Radiation presure***

    Any curve or other characteristics for the radiation pressure noise and other noises in mode cleaner, measured directly or indirectly.

    In which freq range, does the radiation pressure noise become significant as compared to thermal/Seismic noise?
- **COS : Mike Smith**

- *A list of anomalies (scattering, mode distortion, etc) which he thinks could be important, and rough estimation of their effects.*
- *A sketchy list will be enough for now to educate us about these effects.*

- **E2E exports**
  - **Biplab Bhawal**
    - *Understanding modal model*
    - *Mirror phase map*
    - *PSL/IOO*
    - **…**
  - **Andrea Vicere**
    - *Frame interface*
    - *WFS/3D mirror*
    - **…**
  - **Luca Matone**
    - *Servo characterization*
    - *IOO*
    - **…**
  - **Virginio Sannibale**
    - *SUS/SEI*
    - *Validation by comparing with data*
    - **…**
  - **Hiro Yamamoto**
    - *Improvement of environments*
    - *e2eLIGO*
    - *distribute template package to sites*
    - **…**

- **Advanced LIGO**
  - ***Optics***
    - **Compound cavity calculation of the dual recycling Michelson cavity.**
    - **Thermal lensing / thermo-elastic effect**
      - **Calculation of the deformation**
      - **Calculation of fields in deformed optics**
        - *"Best base" is calculated for the deformed mirror*
      - **Relationship with Melody**
  - ***Other known noises***
    - **Radiation pressure, or what else important?**
  - ***Mechanics***
    - **MSE based Quad-pendulum model**
    - **How to migrate from now to the future?**

- **What kind of integration efforts are necessary to utilize the existing resources most efficiently ?**