Design of an Image Generation Truth Model for Testing Attitude Determination Algorithms for a Star Tracker

Master of Science in Aerospace Engineering

Adrianna Y. Fukuzato

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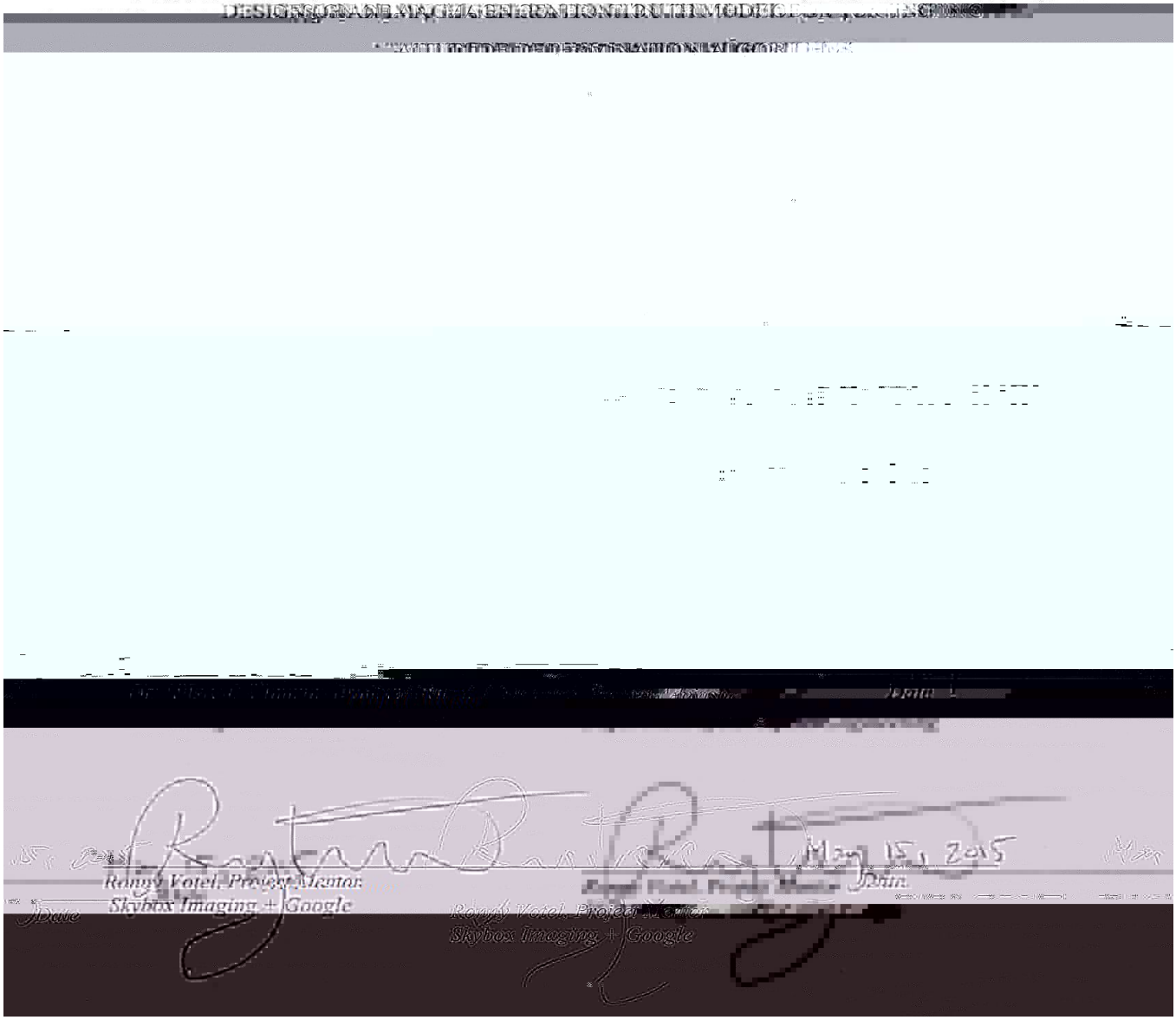
The Designated Project Committee Approves the Project Titled



Ramon Vatel, Project Mentor
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Ramon Vatel, Project Mentor
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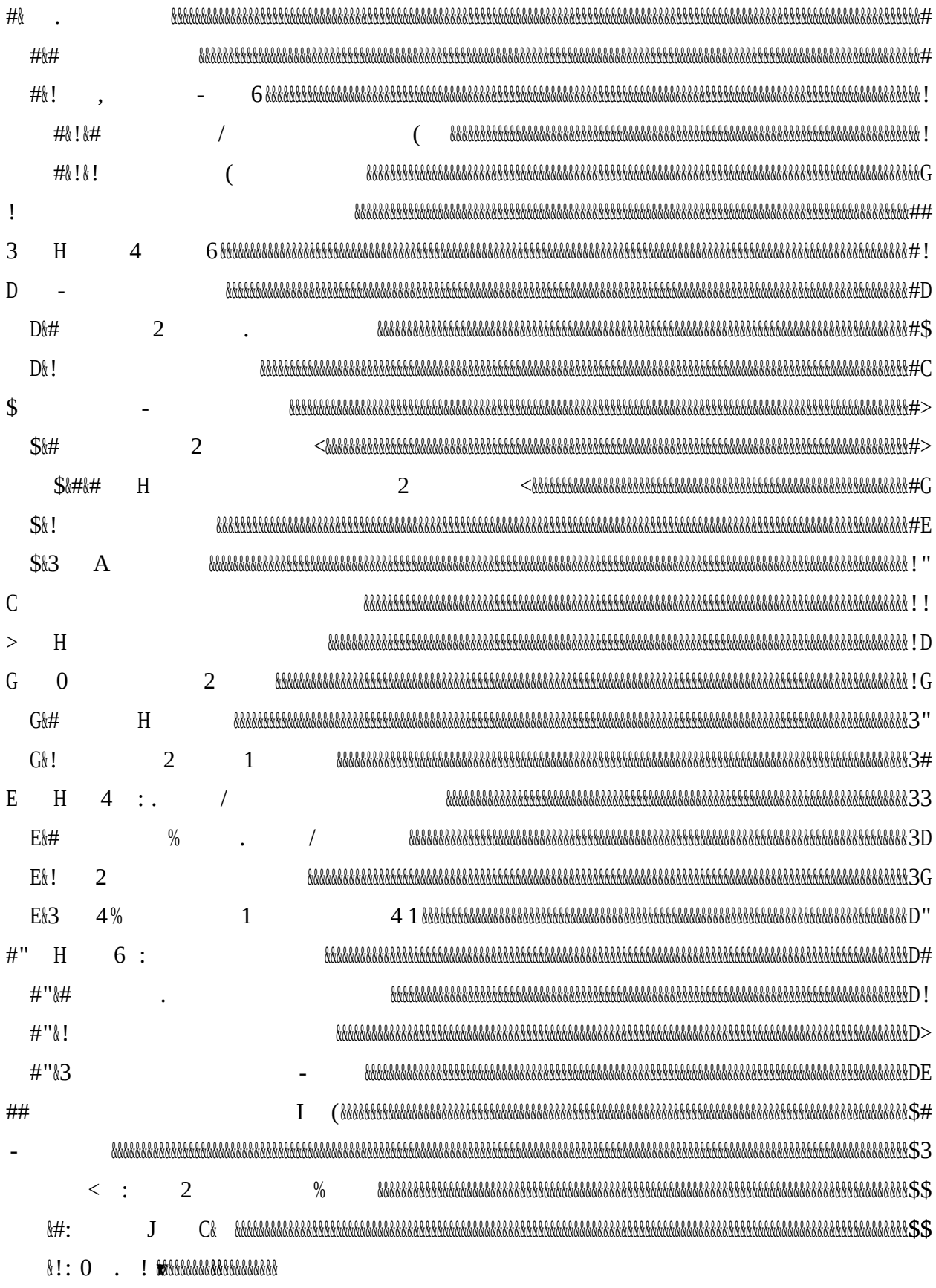

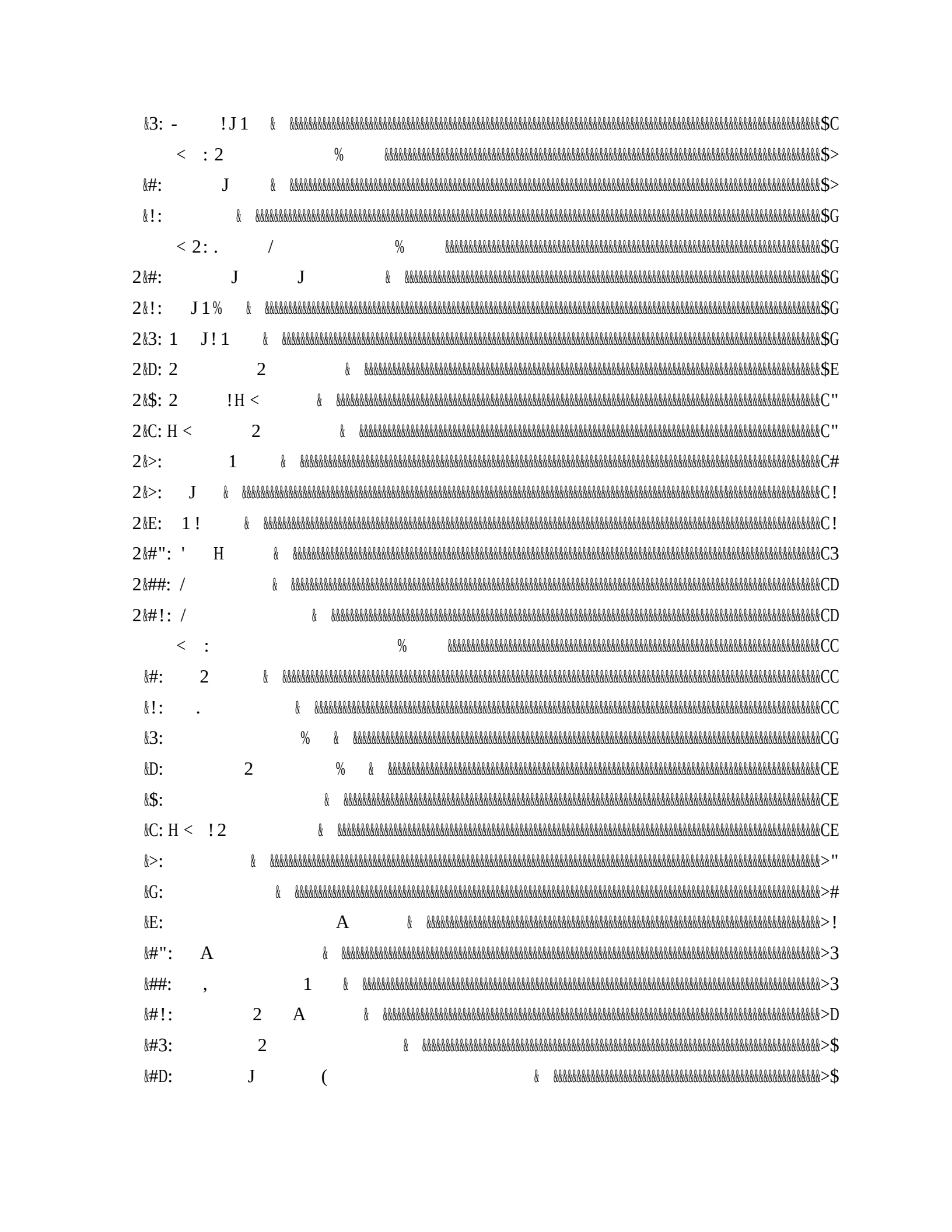

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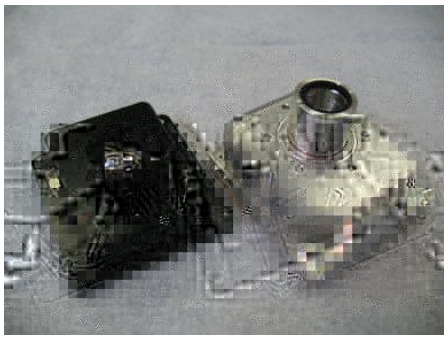

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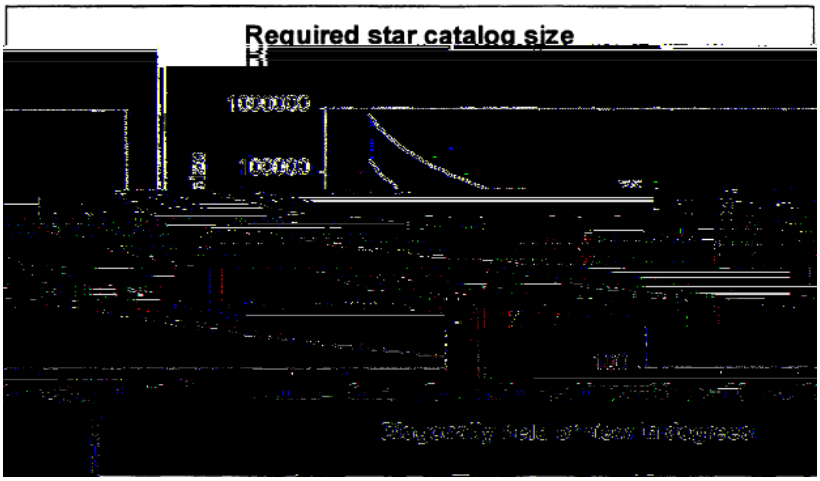

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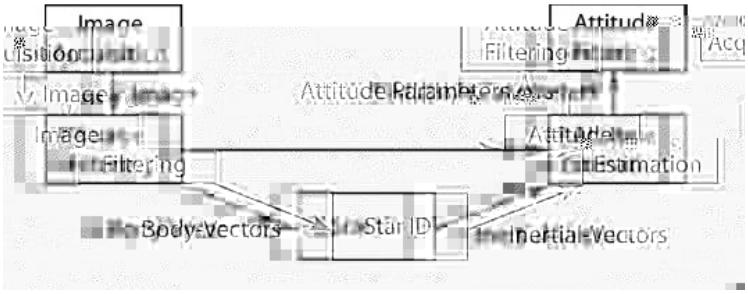

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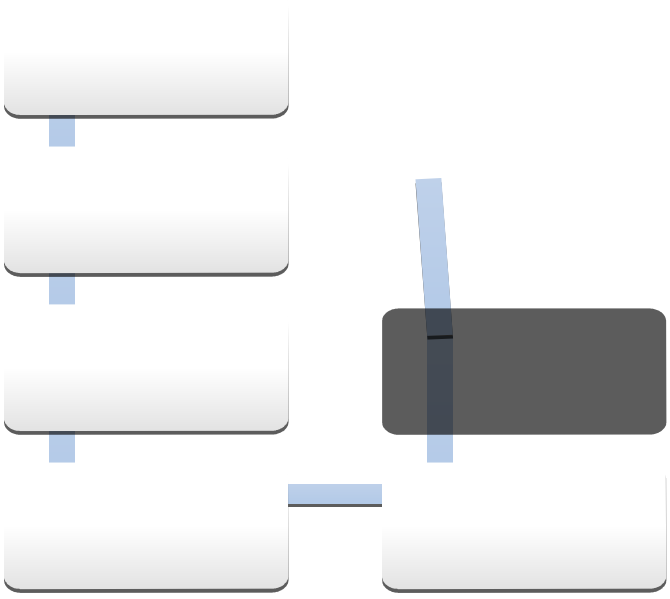

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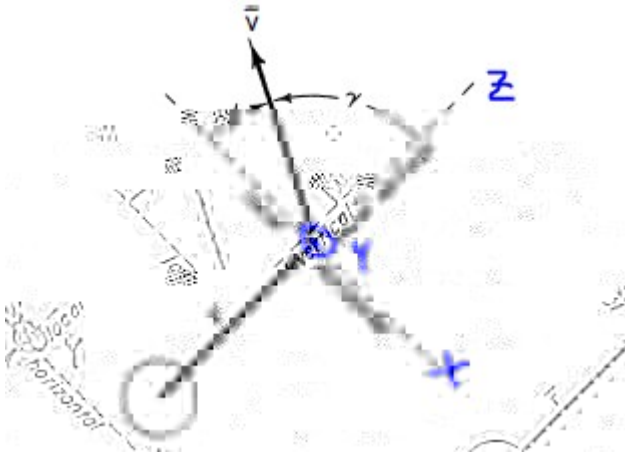

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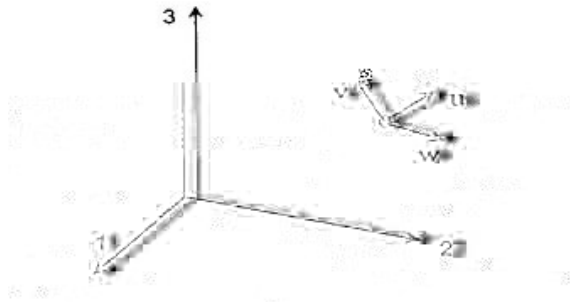

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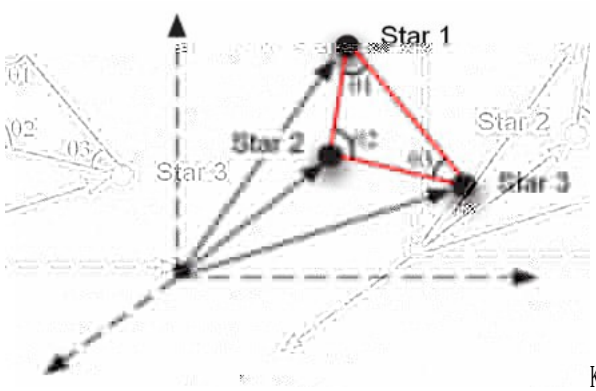

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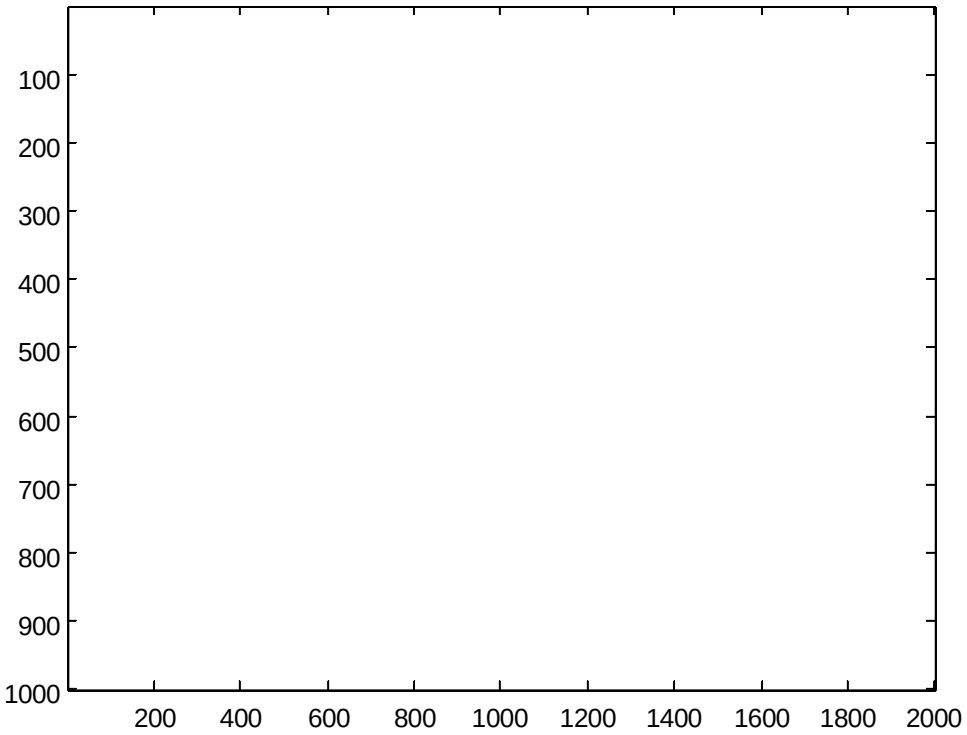

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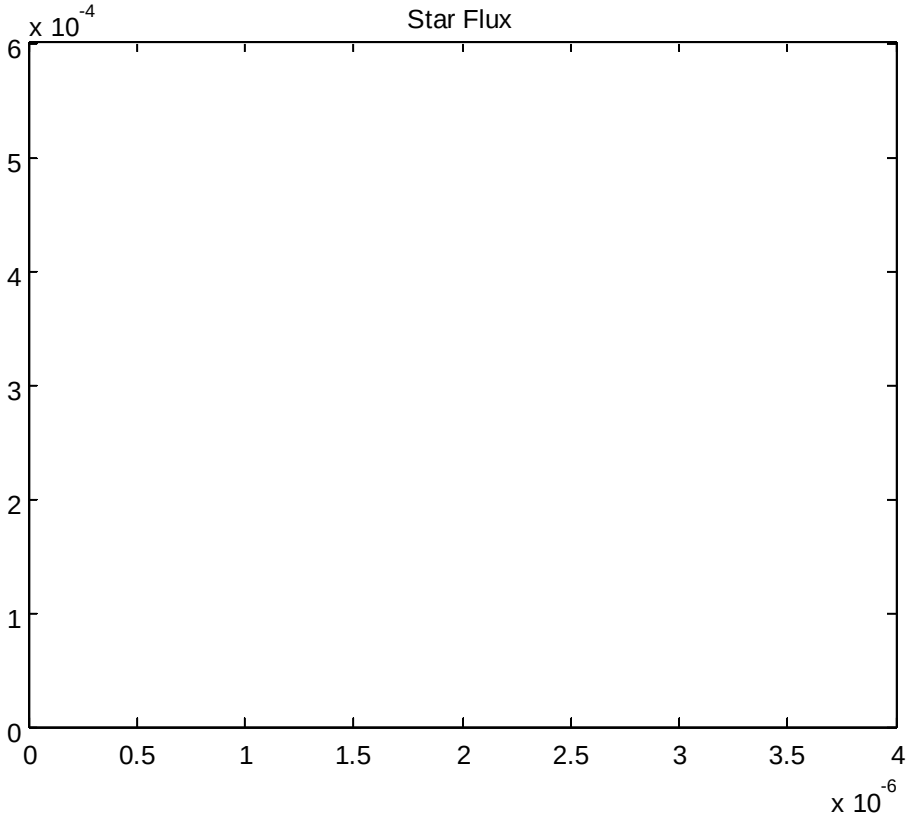

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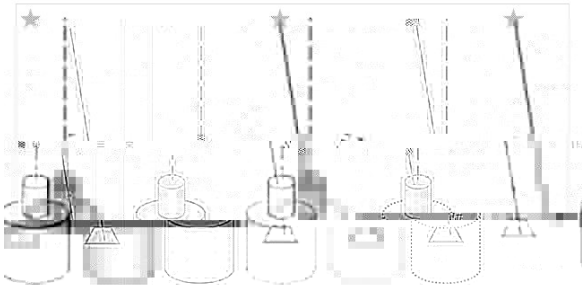

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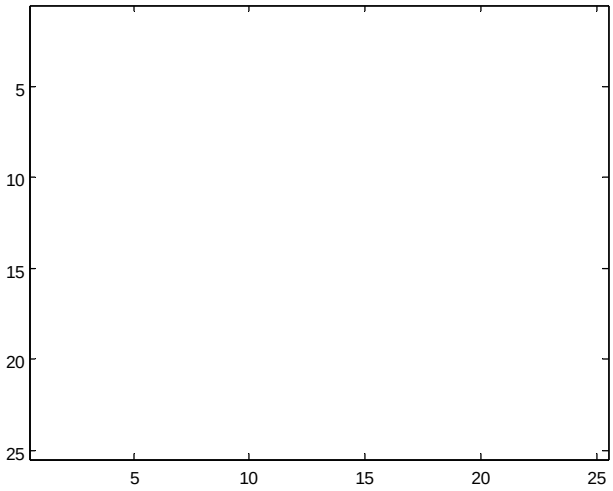

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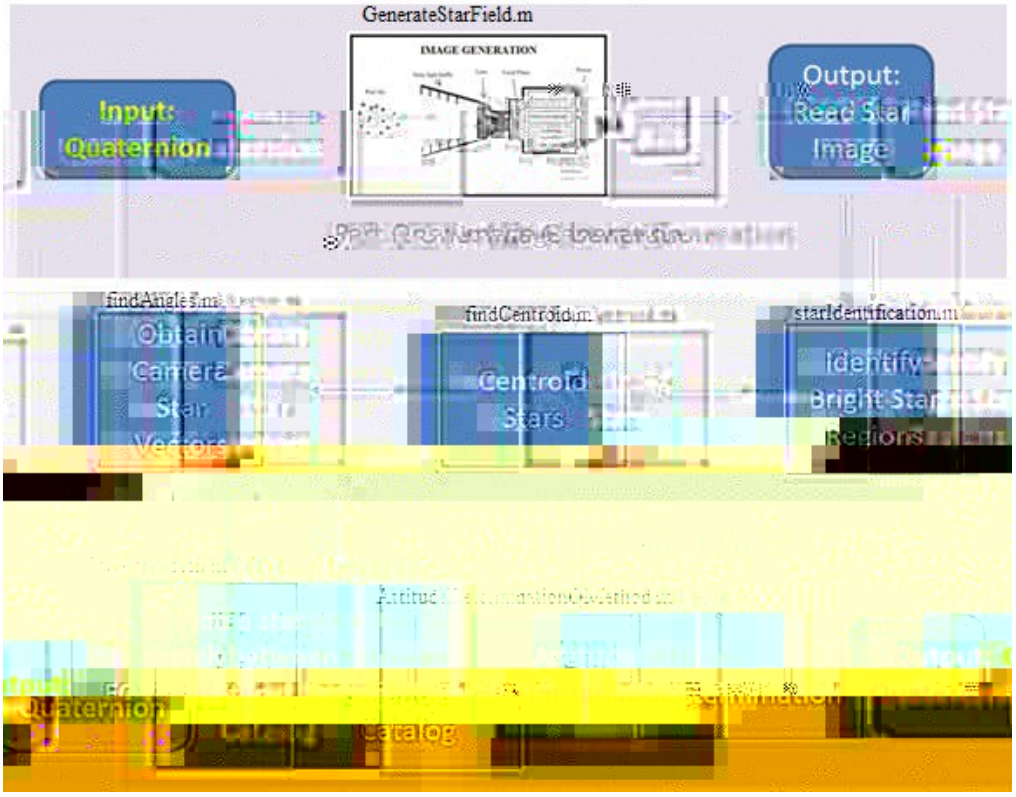

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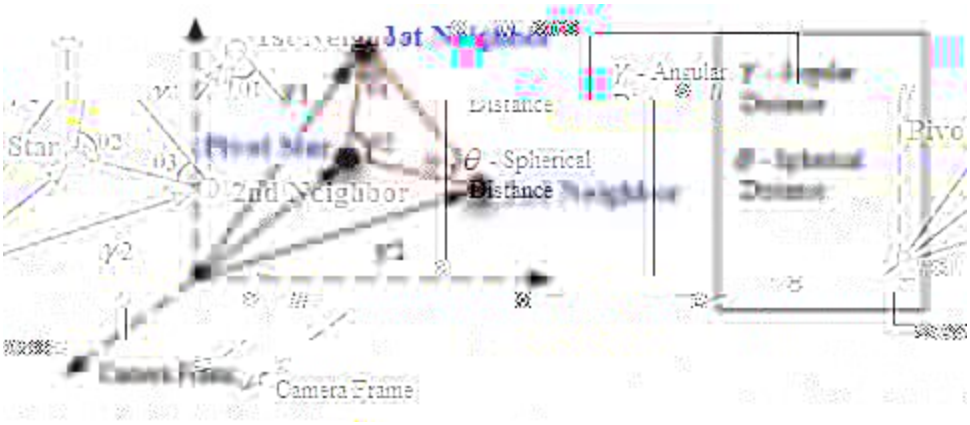

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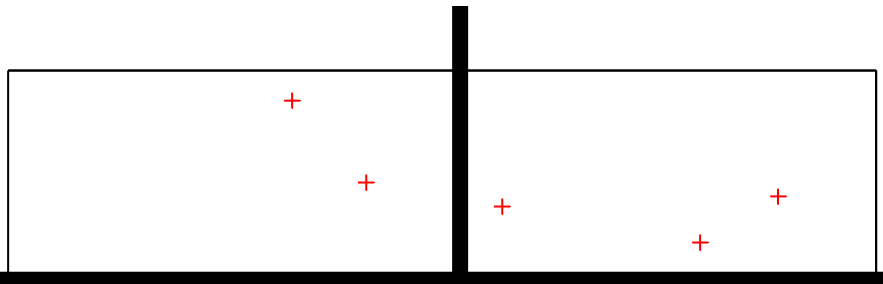

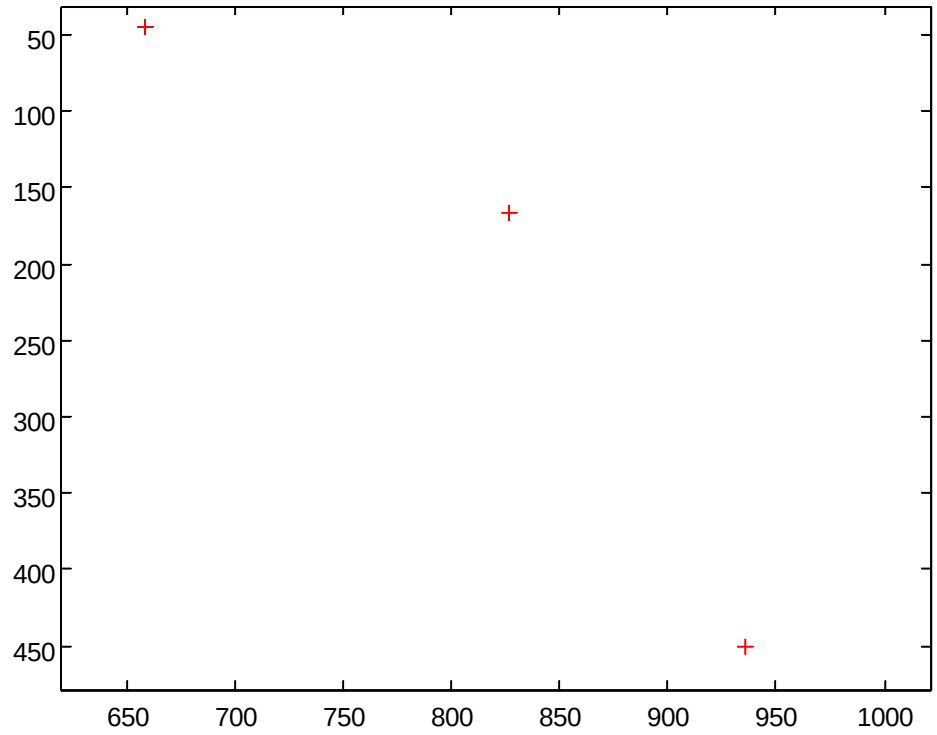

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. ! $75 % & ! $ 5 %(
. ! $75 % & ! $ 5 %(
. ! $75 % & ! $ 5 %(
. !. $75 % & !. $ 5 %(
. ! $75 % & ! $ 5 %(
. !? $75 % & !? $ 5 %(
!

```
@    &     .   !?       $ 5 %(
@    & @    3@   $J5@   %(
     .   !           $ 5 % & @   #(
```

C..: Camera$(i/elS-ace.m

```
                                                                    -

                          5 -515F
                5                A -

        * 5 + &       3A -       $     5 -5 15 F%

  &      ! (
   &      !  (
I &      !I(
@ &      !@(

   & $ID3%/'(
   & $@D3%/'(

  &  D F(
  &    6 $ -  %D  (
  &    6 $ 1  %D  (
```

C.2: (i/elS-aceCoordinates.m

```
                              -
                        7  #  H @
               J         5             5     .
               I           .                "      -
  H                   3A -

            .    & A -                  $J5     5    .   %

       &     .   !           (
  &       $       %(
     & '
   * 5 + &       3A -       $     5       $ 5'%5       $ 53%5       $ 54%%(
       .   !A -       $ 5'% &  (
       .   !A -       $ 53% &  (
```

C.3:)ohnson 8 cur#e.m

```
                M       @
                $    DD .    !     !  D  .D      D       D  8'!@L%
                N               I   1

                         "          5 M       @


          *    .  5M@     + & L      @     $%

    .   & $9 9 4988% ' 6:(
     & F    $<:5'%(
.       & F    $99:5'%(
>&*8!883!33!Â ß &*8)883!33!¶ ß &*8)883!33!ÐAÁþ 3;rIHRS ß &*'!883!33!Ð¾Ã¼
```

```
8!8=3
8!84;
8!849
8!84
8!83<
8!834
8!8':
8!8'
8!8'=
8!8'3
8!88:+(
M@      & *   ( > (.     +(
```

C.3: ref@star.m

```
                                  -                    "
                                                        .      E  A

                    #     -
  H             L      @     5          1     7 O   #                "

                - &          $%

      &  ! 3  '8C64=(               *M  + A    7#
    7 & '!4<8 9 '8C634(             *MDP+ G   F    #
      & 3!::; '8C<(                 * D +
       N & 9;;;(                    *P+
    >I & '=:9:;<;'888(              * + >            I
    ,  &  :9<88888(                 * +    #
        & $>ID, %C3(                    DD     !   !  D   D   D  FF 7DA 1 6
Q  D  8=636       !
    *   .  5 M@+ & L      @     $%(

      & $$3       C3%!D$   .  !C9! $ - $$   %!D$   .  ! 7    N%%6'%%%#(
       - &      F$   .  5 ! M@%(                #              *OD 3+
           - & $   -D    %(                 ?    #           *OD 3D +

        $   .  5 %
         $#     H  -#%
    -  .  $# R    .    * +#%
    1  .  $# *O D  C3+#%            O      "$   .  5 ! M@5   N%(
```

C.9: 5 8 $Tem-.m

```
                0                                      G6@           -
                G6@          -
```

N

N & G@3N $. %

N & = 88 $ 'D$!:3 . / '!;% / 'D$!:3 . /! 3% %(

C."=: Aum(hotons.m

. S6Q
5 1 - "
@ 5 G@ -5
" 5 .
H L @

* . 5 + & E A $@ 5. 5 %

* 575 5 N5 + & $%(
& ! (
> & !>(
* . 5M@+ & L @ $%(
N & G@3N $. %(

& $$$3 C3%!D$. !C9! $ - $$ %!D$. ! 7 N%%6'%%%%#(
& (*OD 3+ M@
& F$. 5 ! M@%(*OD 3+
& 3!9'3C$63 !;6@ %(
? & $$ %!D . %#(

H - & $ D % ! (*OD 3D +
H - & $$ D % ! %!D?(* D 3D +
& H - >(* +
$ H -%(

& $$$3 C3%!D$. !C9! $ - $$ %!D$. ! 7 N%%6'%%%%#(

$'%
$. 5 5#.#%
$# H - 6 , #%
$#@ & 63 !;#%
- . $#R . * +#%51 . $#*O D C3+#%

$3%
$. 5 H -5# #%
$# H -#%
$*#@ & #5 3 $@ %+%
- . $#R . * +#%51 . $#*O D C3+#%

O "$. 5 H -5N%(

C."": GenerateStar.m

```
                                                    5          1
"
```

A J
J
- " 5 "
- 5 @ 5
5 .
H 5 A - 5 0

* 5 + & 0 H $J%

& $%(
. & $J5 %(
& A - $J5 5 . %(

I@ & !A - (
@ & ! (
. & !. (
I & !I(
@ & !@(
E F & !E F (
& F $@5I%(

& *+(
!I@ & I@(
! & ! (
! & @ (
! & ! (

& ' $ I@%

& @ $ %(
G@ & . $ %(
& I@$ 5'%(
& I@$ 53%(
* 5 5 + & 0 $ 5G@5 5 5 %(

& /' /E F (
& /' /E F (
& 8 T)& '888(
& 8 T)& 3888(
$ $ %5 $ %% & $ $ %5 $ %% /
$ 5 %(
5 " 1 # H @

$ %(
$ 1%(

D.": findCentroid.m

```
                H
                75                                  -                5 ,
                          $,  %
                             S6   5              U6

         *   S5   U+ &             $75 5,    %

 - &       $,    $ 5'%%(
 1 &       $,    $'5 %%(
 1 & F    $ -5 1%(
 - & F    $ -5 1%(

         &  (
    77 & '  -
           & '  1
         1$775  % & ,    $775  % 7(
         -$775  % & ,    $775  %  (
          &   / '(

    7 & 7 / '(
      &         (


   U &    $ 1$ %%D   $,    $ %%(
   S &    $ -$ %%D   $,    $ %%(
```

D.$: starIdentification.m

```
                                                  $,  %
                                                                "    "!
                O
                    Q    -
                                 5 ,             "                  #
                         5     #    -           5     #  ,   "    "
  H

         *,  5         + &                  $   %

      &             $%(
E  F  &      !E  F (
  -              & 4(

 Q0 &    (
,   & *+(
     & '(
```

```
   "L & 39(

   & 39       $ Q0$ 5'%%639(
    LL &        "L       $ Q0$'5 %%639(
  &   (
L & LL(

    Q0$ 5L%  &   -
          L & '(
          L & '(
            & '(
            & '(
         3L & '(
    "      Q0$ 5L/'%  &  Q0$ 5L%
        L & L / '(
             3L &      3L / '(

    "      Q0$ /'5L%  &  Q0$ 5L%
          &   / '(

      "  &  (   "L & L(
    "      Q0$  " 5  "L/'% V& 8
          "L &   "L / '(
              L &       L / '(
            "L && '
           .   7


      "  &  (   "L & L(
    "      Q0$  " 5  "L6'% V& 8
          "L &   "L 6 '(
              L &       L / '(
            "L && '
           .   7


      "  &  (   "L & L(
    "      Q0$  " 6'5  "L% V& 8
          "  &   "  6 '(
              &         / '(
            "  && '
           .   7


      "  &  (   "L & L(     "
    "      Q0$  " /'5  "L% V& 8
          "  &   "  / '(
              &         / '(
            "  && '
           .   7



       , & *#    #5   3   $    %+(
    ,  !$    ,%!  &  Q0$ 6         /       5L6      L L/      L%(
    ,  !$    ,%!    $'5'% &   6        (
```

```
     ,  !$    ,%!    $'53% & L 6       L(
     ,  !  -      $    % &   -$,  !$    ,%! $ %%(
      Q0$ 6         /       5L6      L L/      L% & 8(
          &      / '(
            "L &      3L /       L(



        "L & 39(



       & F    $    6'53%(

         & '     6'
     , & *#    #5   3   $       %+(
,      & ,  !$    ,%! (
7 & ,  !$    ,%!    $'5'%(
  & ,  !$    ,%!    $'53%(
*   S5   U+ &             $75 5,    %(
          €
```

D.+: createStarCatalogDatabase.m

```
                                        -                       #

                                5 A -


                        @       & A -  3            $      5 A @  %

    & $      !ID3%/'(
    & $      !@D3%/'(

             @       & F     $45'%(
@- @F & $    6 A @   $'%%       !  D      ! (
@1 @F & $    6 A @   $3%%       !  D      ! (
@F &  J   $'6 @- @FC3 6 @1 @FC3%(
@- & @- @F @F(
@1 & @1 @F @F(
             @      $'5'% & @-(
             @      $35'% & @1(
             @      $45'% & @F(
```

D.3: findAngles.m

```
                    .  "
                                        -         !
                                        5                 .
                    NH &

                              3                                          .  "

          *     @       5     @        A -    5NH+ &      >      $          5      %

       &              $%(
      & F     $       $          %/35       $          %%(
       & '        $          %
         ' & *          $ 5 % 6      ! D      !  +#(
         '     & A -  3            $      5     '%(
         L & '        $          %
             - & *          $L5 % 6      ! D      !  +#(
             -     & A -  3            $     -! )ß ð     )ß ð    ‹ !
```

```
    @       A -    & F    $454%(
    @       A -   $ 5'% & *     E    .   6     ! D     !  +#(
    @       A -   $ 53% & *          6     ! D     !  +#(
    @       A -   $ 54% & *      E    .   6     ! D     !  +#(

    @       & F    $454%(
      & ' 4
    @      $ 5 % & A -  3          $    @       A -   $ 5 %%(


NH & F    $'54%(
@' &     @      $ 5'%(
@3 &     @      $ 53%(
@4 &     @      $ 54%(
 ' &     @       A -   $ 53% 6     @       A -   $ 5'%(
 3 &     @       A -   $ 53% 6     @       A -   $ 54%(
> &   °!#ß Ð  Ò@ß@Ó2R€$@35@'%(    & F  ñ%'5 3%(
G &     >              $@35@4%(
  &     >              $ '5 3%(
NH$'5'% & > '<8D  (
NH$'53% & G '<8D  (
NH$'54% &   '<8D  (
```

D.**6:** findStarMatch.m

```
                H              .  "                                    H @
                                X     X "                    .
                                              5
                                 H @
```

```
P & *G/          $G% 6       $G%  1 $4% F(           $F%       $G%+(
*   @5    .  + &     $P%(
J    & *   @$=5=%(     @$' 45=%+(
      & $3      $   @$=5=%%% '<8D  (
```

D."=: get1uaternion,rror.m

```
                .                                        J          !

               ?          J          5 N     J
               >                *    +


                ?      &     B          ?     $J      5J     %


J           & *J      $'% J      $=% 6J      $4% J      $3%(!!!
    6J      $=% J      $'% J      $3% J      $4%(!!!
    J      $4% 6J      $3% J      $'% J      $=%(!!!
    6J      $3% 6J      $4% 6J      $=% J      $'%+(
J     & *6J     $3 =%(  J     $'%+(

J     & J           J     (

        ?      & 3       $J     $=%%(
```

D."": get ossFunction8alue.m

```
               H                                          O  . #      .
               @                       .  1
                                  5 M


         M &         H        @     $     @       5         @       %

 . &     @       (
   &         @       (
   & '(    "


                                                >!
```

```
G  & F    $454%(
G & F    $454%(
      & ' 4
    G  &     .$ 5 %           $  $ 5 %%(
    G & G / G (


F & *G$354%6G$453%( G$45'%6G$'54%( G$'53%6G$35'%+(
P & *G/          $G% 6      $G%  1 $4% F(           $F%       $G%+(
*   @5    .  + &    $P%(             .         .  $=5=%
   .    - &     .  $=5=%(
   .  8 &    /    /   (             "

M &    .  86    .    -( $         $J% P J%(
```

D."$: runMonteCarlo1Method.m

```
                ,
                              J         !                             .
                     ?   Q>N      5
                J
                             .  "
                       ! N       "
                   B Q                           J
```

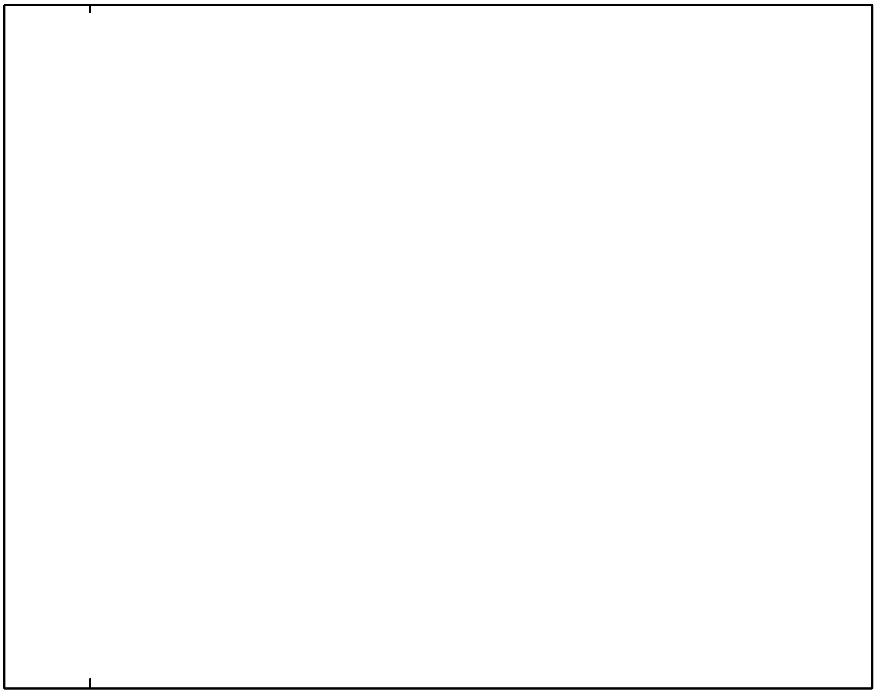
```
        ,   & *#   #5   3   $ %+(
        Q         BQ     !J!$,  % & *J    0   J >     +(
        Q         BQ     !          !$,  % &          (
        Q         BQ     !@      !$,  % & *    @              @      +(
        Q         BQ     !        ?    $ % &         ?    (
```

D."': calcMonteCarloAttitude,rror.m

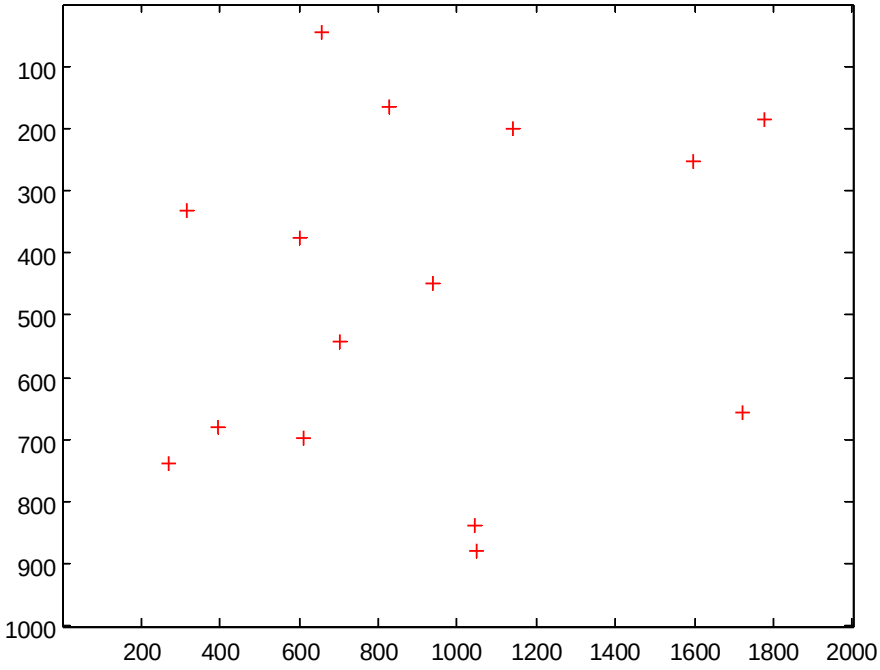
```
                                                    Q
                E   5                              Q         BQ     !
                >                                5 .    8     4 8

    $#Q         BQ     !   #%
>       ?     & Q         BQ     !        ?    (
F       & F    $'8885'%(
        -     & F    $'8885'%(
L & '( 7 & '(

      & '       $>       ?    %

       & >       ?    $ %(
          ) '
       F      $L5'% &    (
       L & L / '(

            '
              -    $75'% &    (
       7 & 7 / '(



      F     & F         8(
F       & F      $      F    %(
      F     &        -       8(
       -     &        -    $      F    %(  8 & 4 8

   K       &     $F      $ %%(
   K       &    $F      $ %%(
   N      -     &     $       -    $ %%(
   N      -     &    $       -    $ %%(
```

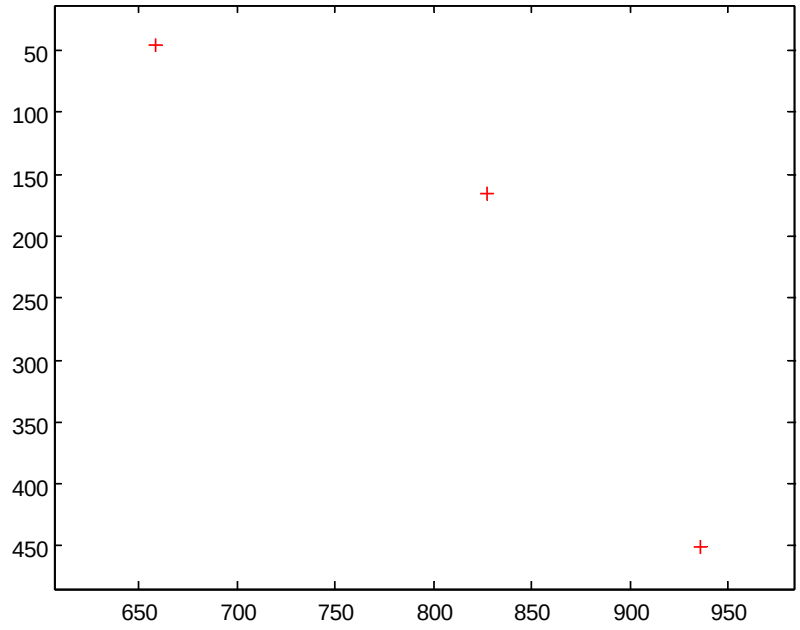
D."+: runScri-t@StarTrackerforAttitudeDetermination.m

```
                N   7     >                    !
```

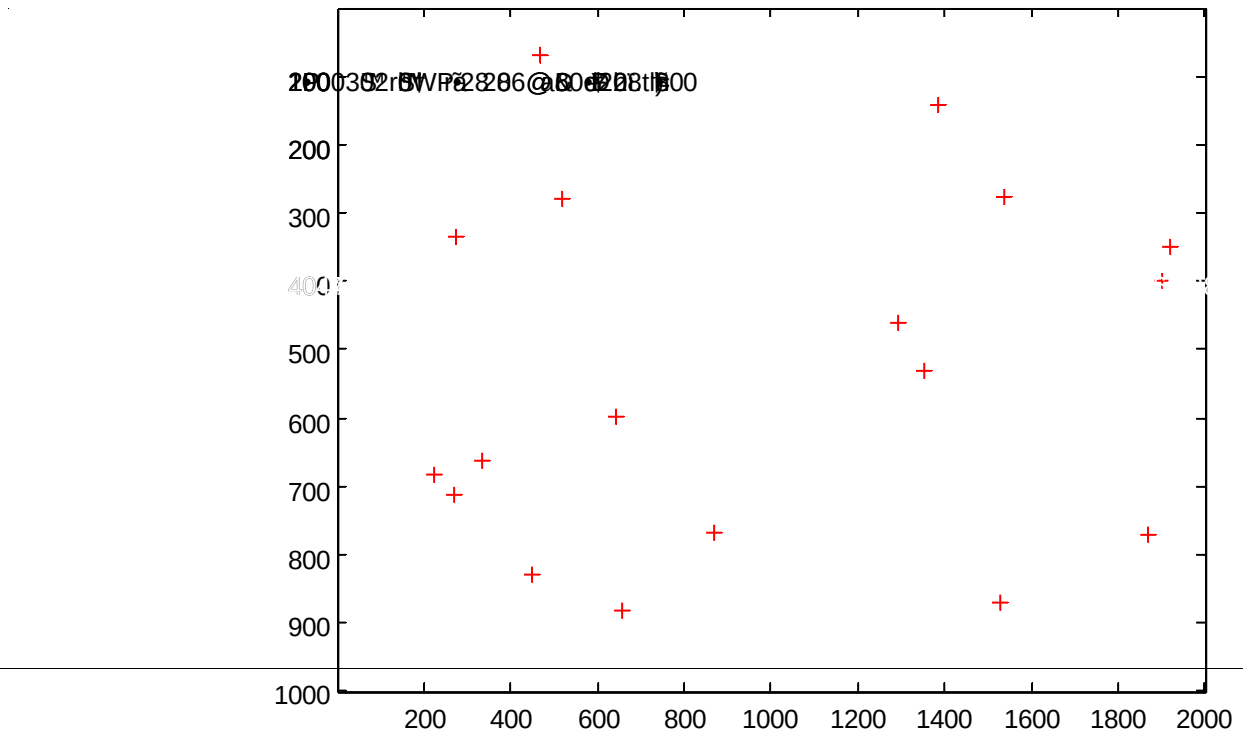


, .$, /am-le Star Identification B Star Matching *ut-uts





>>


200
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1200
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