Comp 401
Thread Coordination

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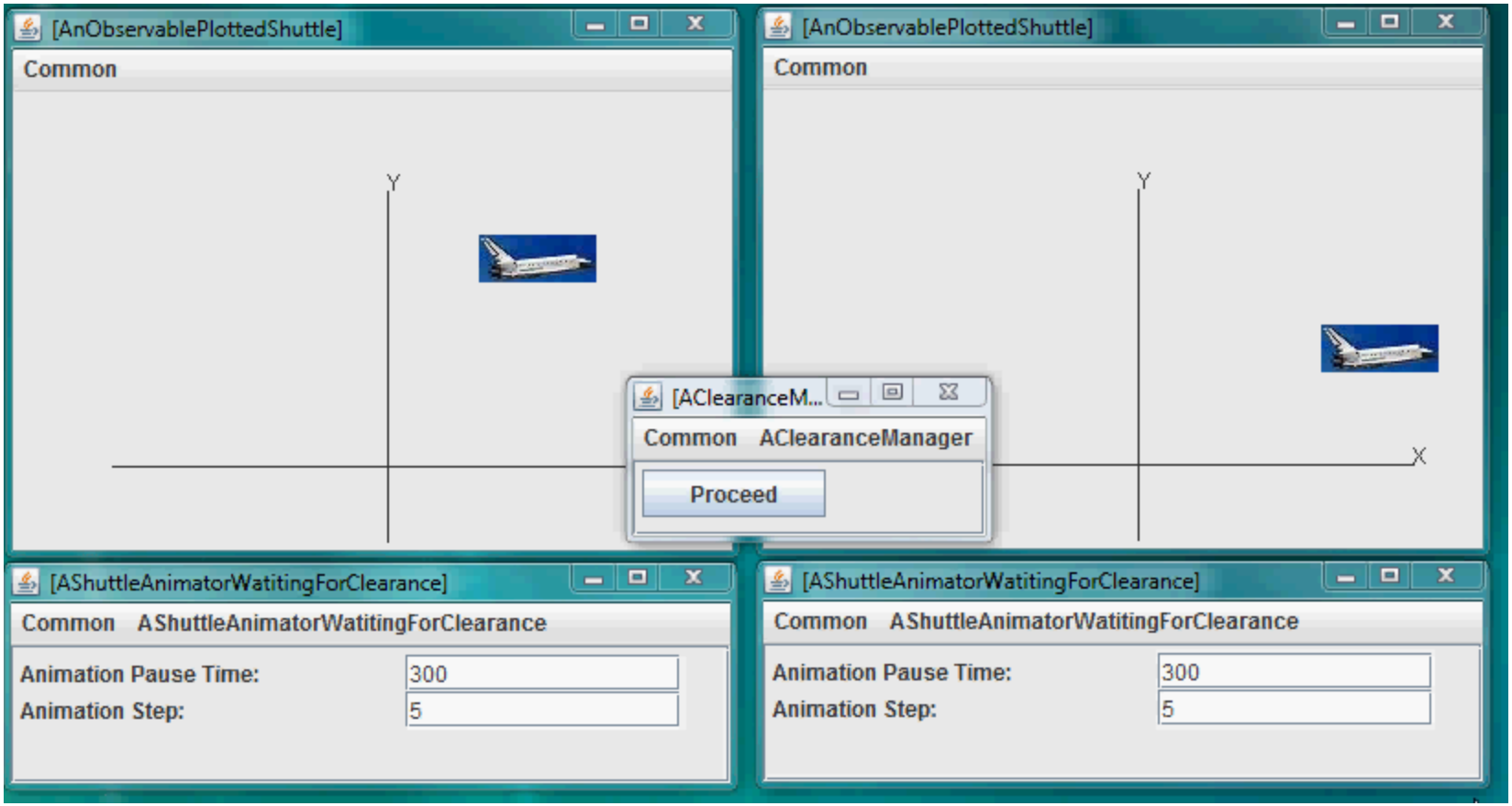
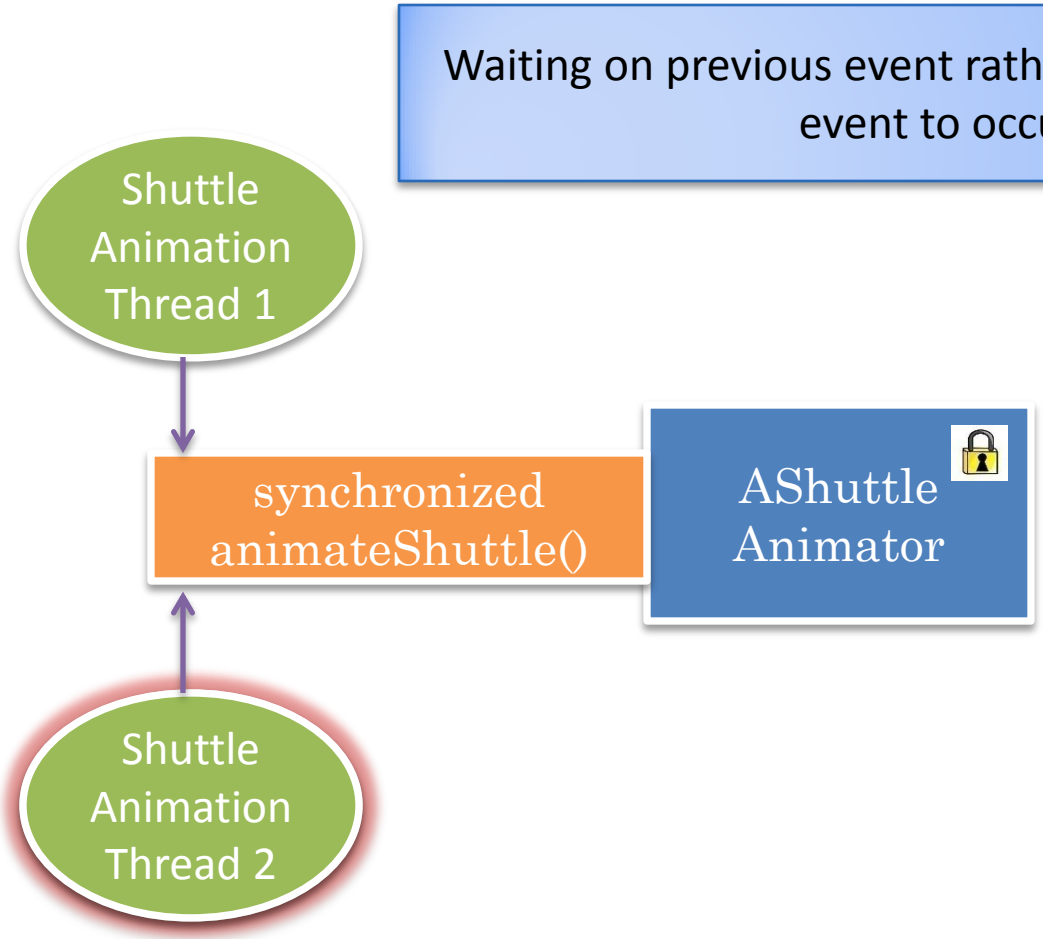
Interactive Traffic Control



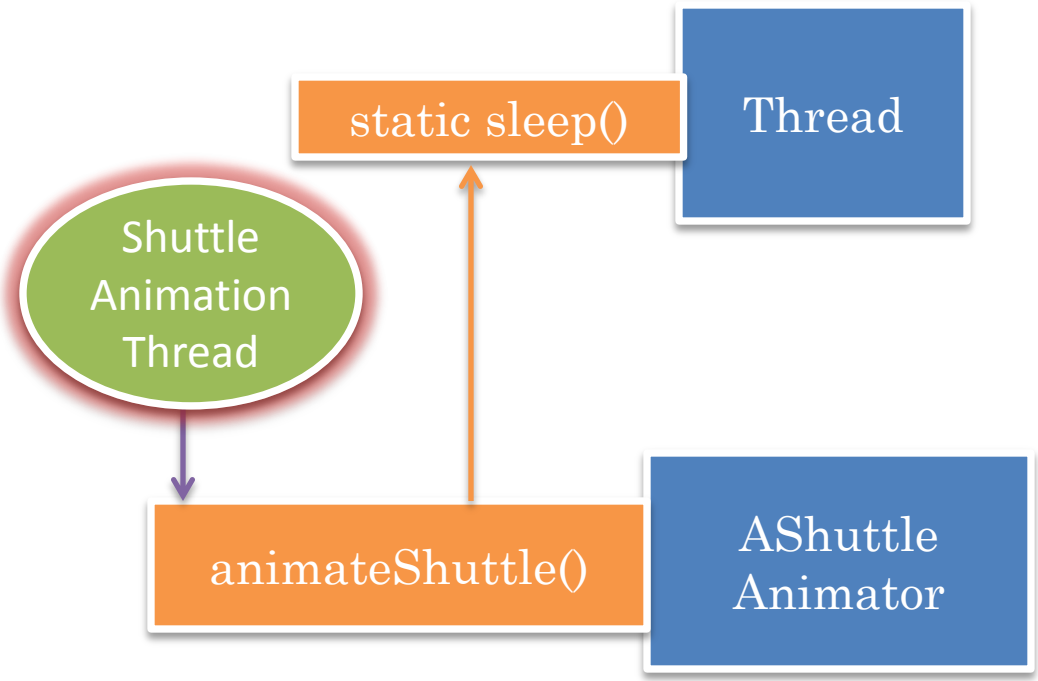
How does a thread wait for an event?

Wait for another Thread to Release Method

Waiting on previous event rather than some future event to occur



Wait for Time to Pass



Could continuously "poll" for event → would not react immediately and would waste CPU time

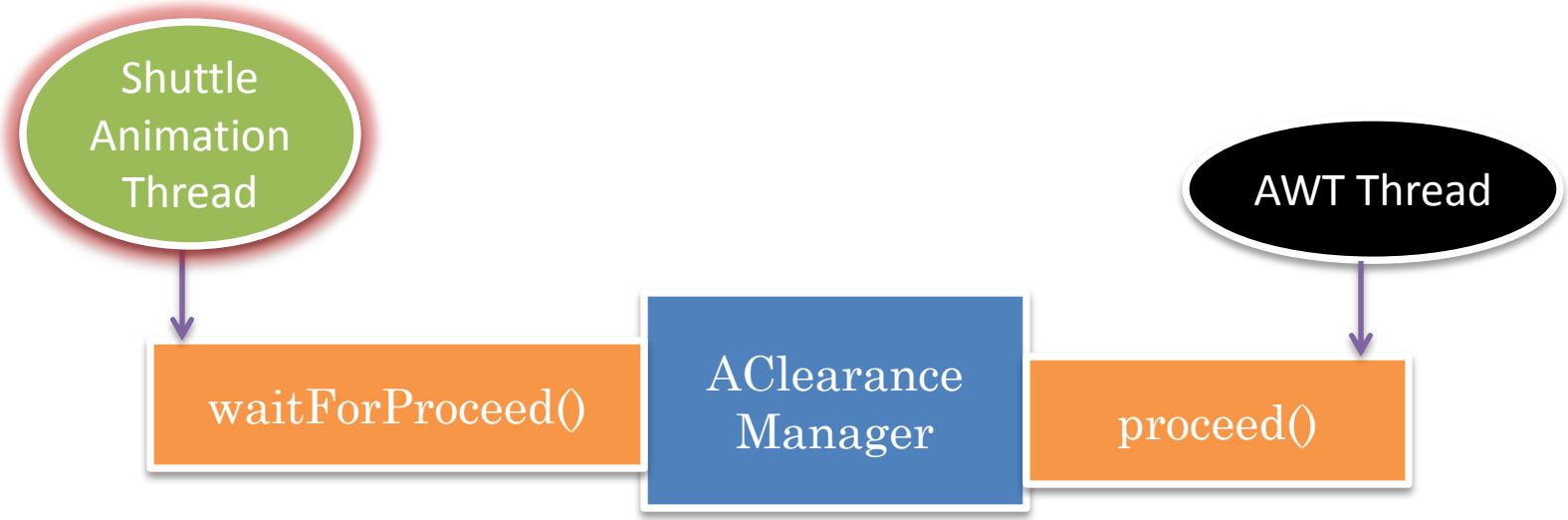
Need to wait for signal produced by some other thread

Analogies

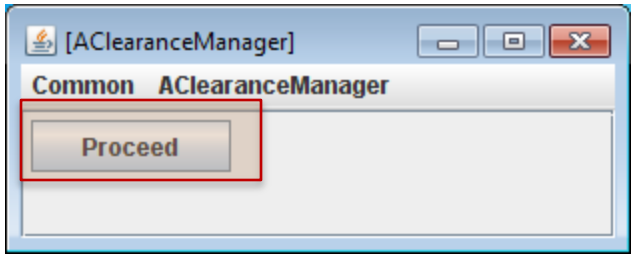
proceed()

waitFor Proceed()

Wait and Notify

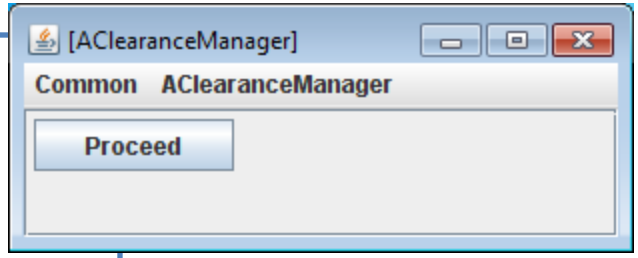



```
ObjectEditor.edit(clearanceManager);
```



Wait and Notify

```
public class AClearanceManager
         implements ClearanceManager {
   @Row(0)
   @ComponentWidth(100)
   public synchronized void proceed() {
     notify();
   }
   public synchronized void waitForProceed()
     try {
       wait();
     } catch (InterruptedException e) {
       e.printStackTrace();
     }
   }
}
```



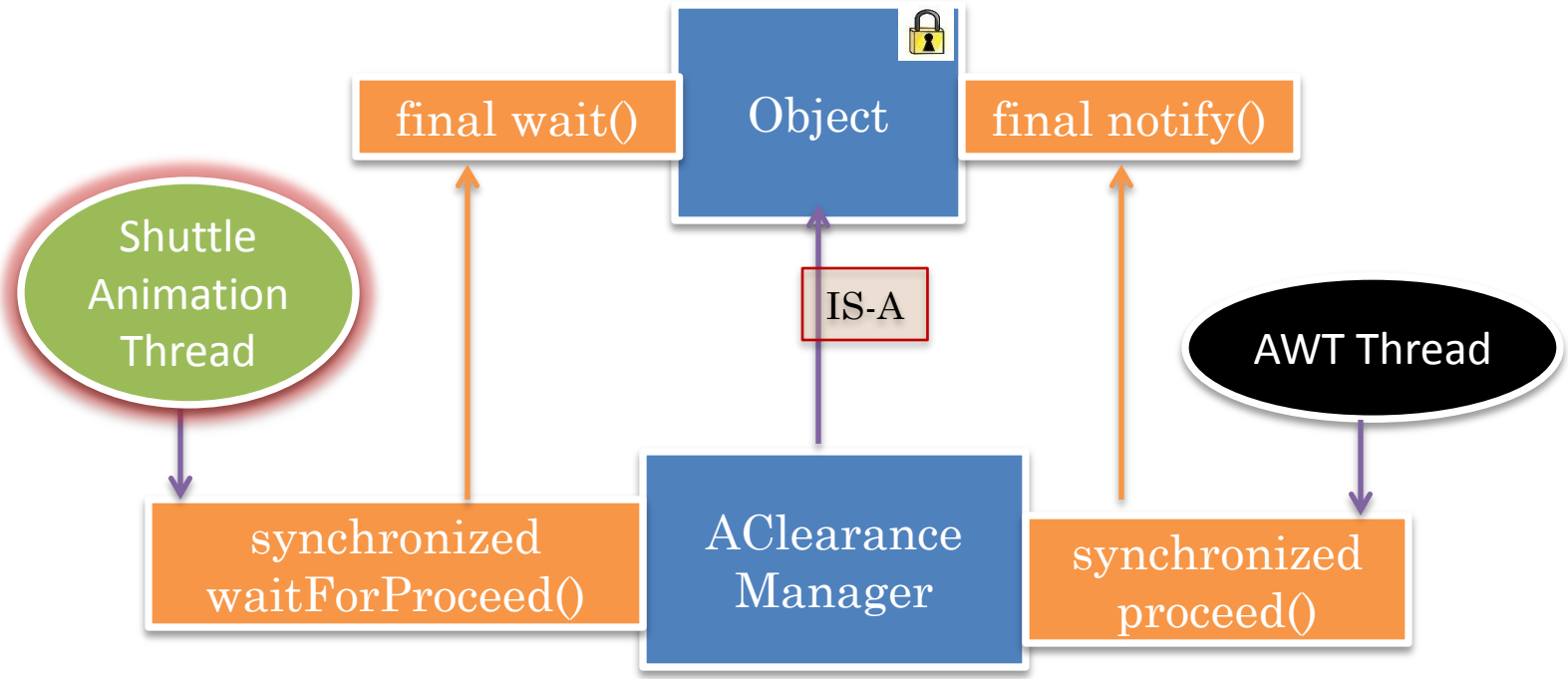
wait and notify() implemented by Object, must be executed in synchronized methods as they access shared Queue

Wait releases synchronized lock on object, makes calling thread wait, and lets some other thread get object synchronized lock

proceed() invoked by AWT thread (executing ObjectEditor code)

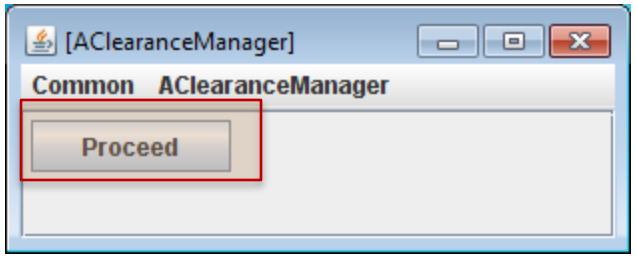
waitForProceed() called by waiting shuttle animator thread

Wait and Notify

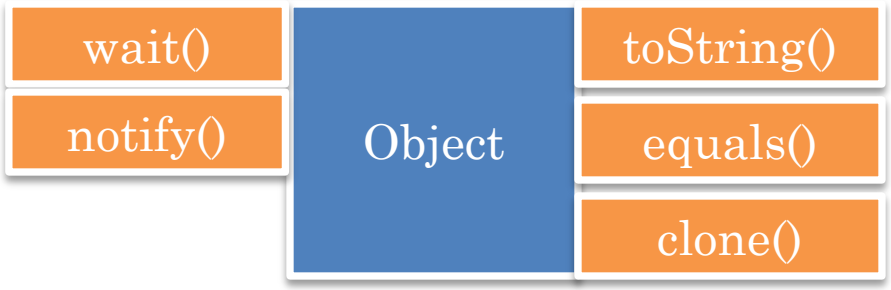


wait and notify must be executed in synchronized methods as they access shared Queue

Wait releases synchronized lock on object, makes calling thread wait, and lets some other thread get object synchronized lock



Wait and Notify Methods



o.wait(): makes the calling thread wait (in a queue) until the next o.notify() call (by some other thread), allows other synchronized methods to execute

o.notify(): if some threads are waiting as a result of o.wait(), then unblocks the first one who waited

wait changes some internal variable (a Queue) in class Object which is accessed by notify

Since shared data structure accessed by multiple threads, wait() and notify() must execute in synchronized methods

Waiting Shuttle Animator

```
public class AShuttleAnimatorWaitingForClearance
                extends AConcurrentShuttleAnimator {
  ClearanceManager clearanceManager;
  public AShuttleAnimatorWaitingForClearance(PlottedShuttle
theShuttle,
                                  ClearanceManager aClearanceManager) {
    super(theShuttle);
    clearanceManager = aClearanceManager;
  }
  protected void animateYFromOrigin(PlottedShuttle shuttle,
                      int animationStep, int animationPauseTime,
                      int startY, int endY) {
    clearanceManager.waitForProceed();
    super.animateYFromOrigin(shuttle, animationStep,
                      animationPauseTime, startY, endY);
  }
}
```

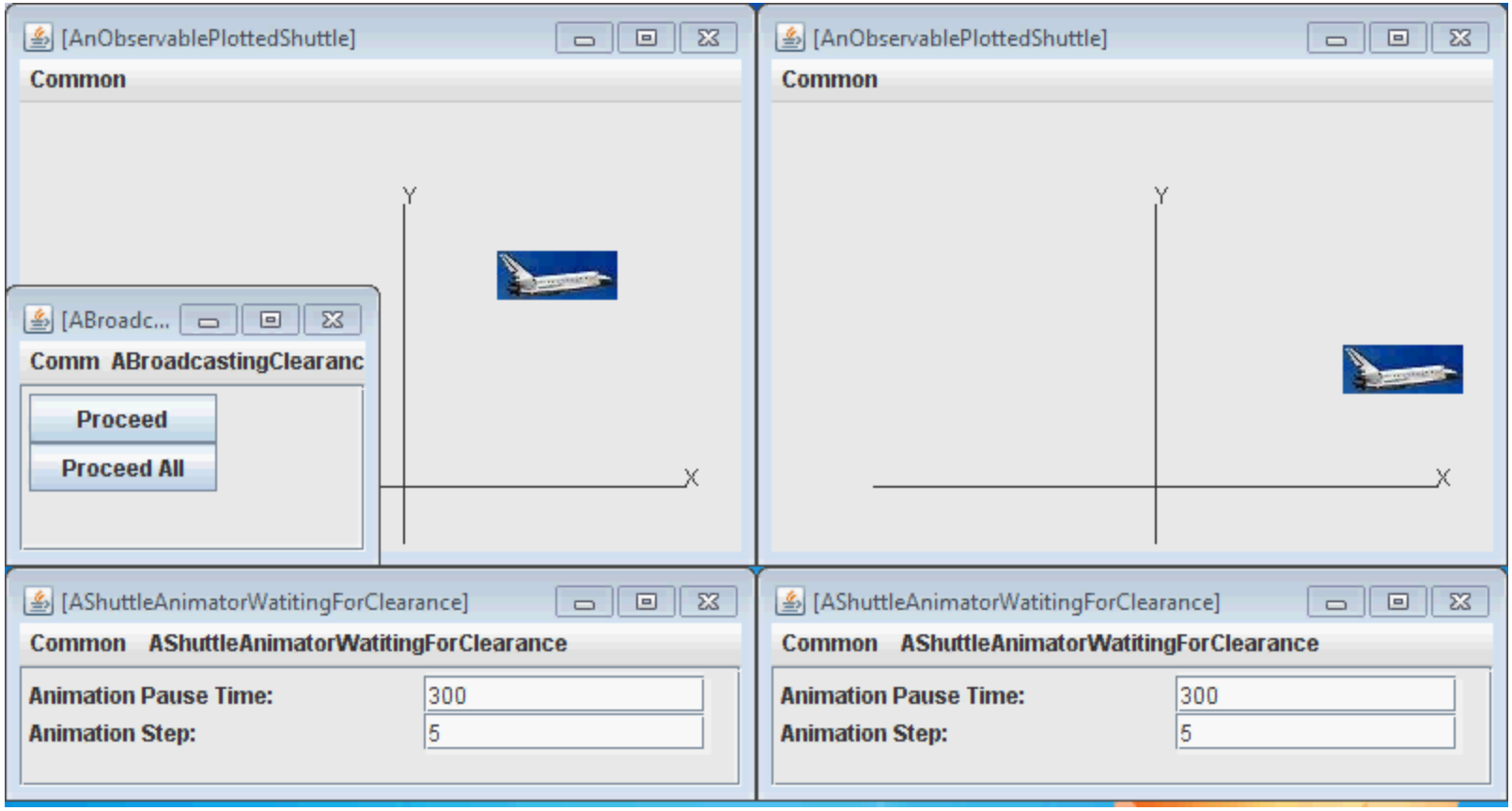
Main

```
public class ManualShuttleTrafficControl
             extends ConcurrentShuttleLaunchAnimation {
  public static int ANIMATOR_FRAME_HEIGHT = 125;
  public static int CLEARANCE_FRAME_WIDTH = 200;
  public static int CLEARANCE_FRAME_HEIGHT = 150;
  static int animatorNumber;
  public static void displayShuttleAnimator(
                       ShuttleAnimator shuttleAnimator1) {
    OEFrame frame = ObjectEditor.edit(shuttleAnimator1);
    frame.setLocation(START_FRAME_X +
      (animatorNumber * SHUTTLE_FRAME_WIDTH),
      START_FRAME_Y + SHUTTLE_FRAME_HEIGHT);
   frame.setSize(SHUTTLE_FRAME_WIDTH, ANIMATOR_FRAME_HEIGHT);
   animatorNumber++;
  }
  public static void displayClearanceManager(
                      ClearanceManager aClearanceManager) {
    OEFrame frame = ObjectEditor.edit(aClearanceManager);
    frame.setLocation(START_FRAME_X,
                       START_FRAME_Y + SHUTTLE_FRAME_HEIGHT/2);
    frame.setSize(CLEARANCE_FRAME_WIDTH, CLEARANCE_FRAME_HEIGHT);
  }
```

Main

```
public static void main(String[] args) {
   ClearanceManager clearanceManager =
      new  AClearanceManager();
   PlottedShuttle shuttle1 =
      new AnObservablePlottedShuttle(SHUTTLE1_X, SHUTTLE1_Y);
   displayShuttleFrame(shuttle1);
   ShuttleAnimator shuttleAnimator1 =
      new AShuttleAnimatorWaitingForClearance(
            shuttle1, clearanceManager);
   displayShuttleAnimator(shuttleAnimator1);
   PlottedShuttle shuttle2 =
      new AnObservablePlottedShuttle(SHUTTLE2_X, SHUTTLE2_Y);
   displayShuttleFrame(shuttle2);
   ShuttleAnimator shuttleAnimator2 =
      new AShuttleAnimatorWaitingForClearance(
            shuttle2, clearanceManager);
   displayShuttleAnimator(shuttleAnimator2);
   displayClearanceManager(clearanceManager);
}
```

Simultaneous Launch



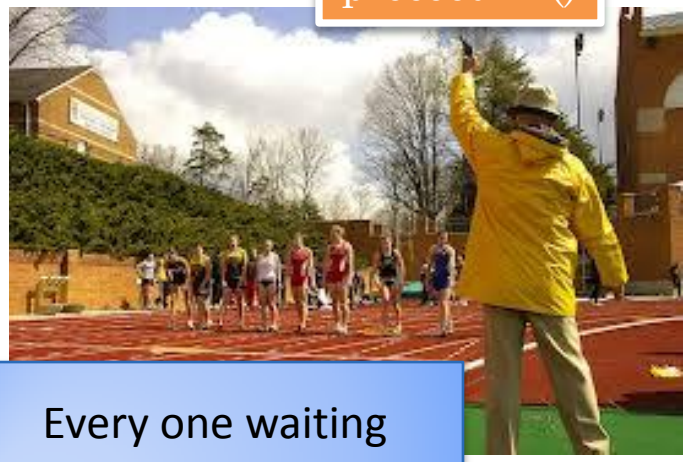
Analogies

proceedAll()

proceed()

waitFor Proceed()

proceedAll()



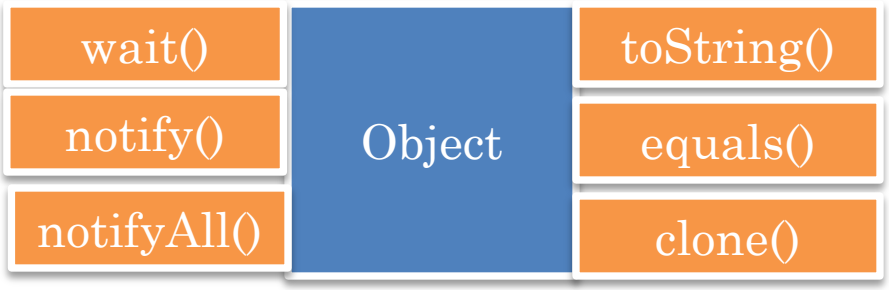
Every one waiting proceeds

One person proceeds

Broadcasting Clearance Manager: NotifyAll

```
public class ABroadcastingClearanceManager extends AClearanceManager
   implements BroadcastingClearanceManager {
   @Row(1)
   @ComponentWidth(100)
   public synchronized void proceedAll() {
      notifyAll();
   }
}
```

NotifyAll



o.wait(): makes the calling thread wait (in a queue) until the next o.notify() call (by some other thread)

o.notify(): if some threads are waiting as a result of o.wait(), then unblocks the first one who waited

o.notifyAll(): if some threads are waiting as a result of o.wait(), then unblocks all of them

Main

```
public class ManualSimultaneousShuttleLaunchAnimation
           extends ManualShuttleTrafficControl {
  public static void main(String[] args) {
    ClearanceManager clearanceManager =
       new ABroadcastingClearanceManager();
    PlottedShuttle shuttle1 =
      new AnObservablePlottedShuttle(SHUTTLE1_X, SHUTTLE1_Y);
    displayShuttleFrame(shuttle1);
    ShuttleAnimator shuttleAnimator1 =
      new AShuttleAnimatorWaitingForClearance(shuttle1,
                                              clearanceManager);
    displayShuttleAnimator(shuttleAnimator1);
    PlottedShuttle shuttle2 =
      new AnObservablePlottedShuttle(SHUTTLE2_X, SHUTTLE2_Y);
    displayShuttleFrame(shuttle2);
    ShuttleAnimator shuttleAnimator2 =
      new AShuttleAnimatorWaitingForClearance(shuttle2,
                                              clearanceManager);
    displayShuttleAnimator(shuttleAnimator2);
    displayClearanceManager(clearanceManager);
  }
```

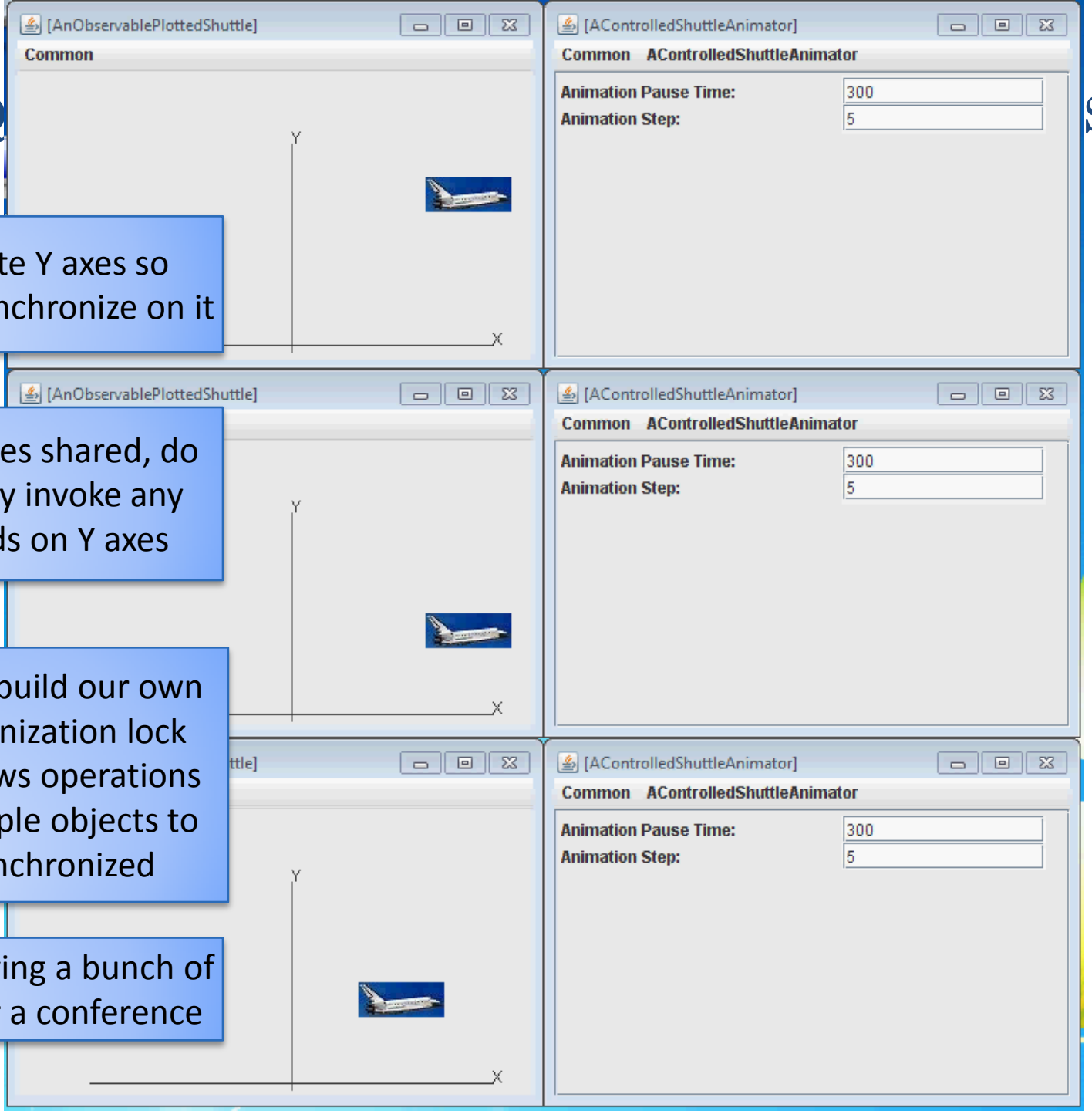
EQ S

Separate Y axes so cannot synchronize on it

Even if axes shared, do not really invoke any methods on Y axes

Need to build our own synchronization lock that allows operations on multiple objects to be synchronized

A la reserving a bunch of rooms for a conference



Lock

```
public class ALock implements Lock {
  boolean locked;
  public synchronized void getLock() {
    if (locked) {
      try {
        wait();
      } catch (Exception e) {
        e.printStackTrace();
      }
    }
    locked = true;
   }
  public synchronized void releaseLock() {
    locked = false;
    notify();
  }
}
```

Coordinated Shuttle

```
public class AControlledShuttleAnimator
                extends AConcurrentShuttleAnimator {
  Lock lock;
  public AControlledShuttleAnimator(PlottedShuttle theShuttle,
                                    Lock aLock) {
    super(theShuttle);
    lock = aLock;
  }
  protected void animateYFromOrigin(PlottedShuttle shuttle,
                        int animationStep, int animationPauseTime,
                        int startY, int endY) {
    lock.getLock();
    super.animateYFromOrigin(shuttle, animationStep,
                        animationPauseTime, startY, endY);
    lock.releaseLock();
  }
}
```

Coordinated Shuttle Main

```
public class AutomaticAirTrafficControl  {
  static final int SHUTTLE_FRAME_X = 50;
  static final int START_FRAME_Y = 50;
  static final int FRAME_WIDTH = 400;
  static final int FRAME_HEIGHT = 275;
  static final int ANIMATION_FRAME_X =
                        SHUTTLE_FRAME_X + FRAME_WIDTH;
  static int shuttleNumber = 0;
  static void createAndDisplayShuttleAndAnimator(int shuttleX,
                                int shuttleY,  Lock aLock) {
    int frameY = START_FRAME_Y + shuttleNumber*FRAME_HEIGHT;
    PlottedShuttle shuttle =
        new AnObservablePlottedShuttle(shuttleX, shuttleY );
    OEFrame shuttleFrame = ObjectEditor.edit(shuttle);
    shuttleFrame.hideMainPanel();
    shuttleFrame.setLocation(SHUTTLE_FRAME_X, frameY);
    shuttleFrame.setSize(FRAME_WIDTH, FRAME_HEIGHT);
    ShuttleAnimator shuttleAnimator =
                new AControlledShuttleAnimator(shuttle, aLock);
    OEFrame animatorFrame = ObjectEditor.edit(shuttleAnimator);
    animatorFrame.setSize(FRAME_WIDTH, FRAME_HEIGHT);
    animatorFrame.setLocation(ANIMATION_FRAME_X, frameY);
    shuttleNumber++;
}
```

Coordinated Shuttle MAIN

```
  public static void main(String[] args) {
    Lock lock = new ALock();
    createAndDisplayShuttleAndAnimator(100, 100, lock);
    createAndDisplayShuttleAndAnimator(100,  50, lock);
    createAndDisplayShuttleAndAnimator(50,   50, lock);
  }
}
```

Wait, Notify, NotifyAll

- Methods provided by Object
- Can be used to make threads wait until some condition decided by our program is met.
- Wait on an object makes a thread block until a notify or notifyAll() is executed on that object
- All three methods must be executed in synchronized methods of the object.
- Waiting thread releases synchronized Object lock so some other object can execute notify() or notifyAll() on that object.
- Notify() and notifyAll() can be executed when condition to proceed occurs
- There are complicated ways to use them you will see in OS courses

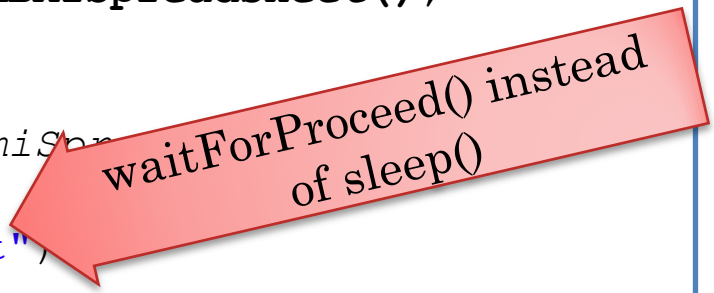
Sleep for Demoing

```
public class ABMISpreadsheetInteractiveDemoer {
  public static void main (String[] args) {
    ClearanceManager clearanceManager = new AClearanceManager();
    ObjectEditor.edit(clearanceManager);
    BMISpreadsheet bmiSpreadsheet = new ABMISpreadsheet();
    bmiSpreadsheet.setHeight(1.77);
    bmiSpreadsheet.setWeight(75);
    OEFrame editor = ObjectEditor.edit(bmiSp
    ThreadSupport.sleep (2000);
    editor.select(bmiSpreadsheet, "Weight");
    bmiSpreadsheet.setWeight(70);
    editor.refresh();
    ThreadSupport.sleep (2000);
    editor.select(bmiSpreadsheet, "Height");
    bmiSpreadsheet.setHeight(0);
    editor.refresh();
    ThreadSupport.sleep (2000);
    editor.select(bmiSpreadsheet, "Weight");
   bmiSpreadsheet.setWeight(0);
   editor.refresh();
  }
}
```

sleep() to give viewer a chance to see the result

MAIN

```
public class ABMISpreadsheetInteractiveDemoer {
  public static void main (String[] args) {
    ClearanceManager clearanceManager = new AClearanceManager();
    ObjectEditor.edit(clearanceManager);
    BMISpreadsheet bmiSpreadsheet = new ABMISpreadsheet();
    bmiSpreadsheet.setHeight(1.77);
    bmiSpreadsheet.setWeight(75);
    OEFrame editor = ObjectEditor.edit(bmiSp
    clearanceManager.waitForProceed();
    editor.select(bmiSpreadsheet, "Weight");
    bmiSpreadsheet.setWeight(70);
    editor.refresh();
    clearanceManager.waitForProceed();
    editor.select(bmiSpreadsheet, "Height");
    bmiSpreadsheet.setHeight(0);
    editor.refresh();
    clearanceManager.waitForProceed();
    editor.select(bmiSpreadsheet, "Weight");
   bmiSpreadsheet.setWeight(0);
   editor.refresh();
  }
}
```



Interactive Demoer