Run to failure experiment C5 - digital twin informs true system, true system not allowed to explore

- repeat of C4 (and C3), but adjusted the rul step on position error (digital twin) due to true system failing during runs.
- was restarted midway (picked up where it left off)

In this work remaining useful life (RUL) refers to the total flight time possible for a single mission. Hypothesis here is that the true system should never fail now. But I see that true system will select an explored trajectory if the digital twin passes it, this might be risky, we need to consider dynamic risk. This is in contract to some of our previous work where RUL referred to the entire life of the UAV across multiple missions. This time the digital twin is simulated multiple times for a distribution. 4th simulation in this track, the true system is not allowed to explore trajectories now, and micro updates are made to the rul when some (not all) digital twin missions do not result in success.

Simulation Steps

The first step is to load the models, provide an initial RUL estimate (using manufacturers information on the battery is a good starting place), and load some workspace variables. 1D polynomial fitting is used to approximate the degradation rate, and thereby predict the mean of the future degradation value distribution. These predicted values are then passed to a digital twin, which is simulated multiple times to generate a monte carlo distribution of variables tracked such as ending state of charge and voltage and mission outcome. The RUL is updated based on the result of the digital twin simulation, and then the new RUL is used by the real system for trajectory selection. The steps are as follows:

1.

Uncertainty Quantification

Trajectories

load main workspace

```
end_sim = 0;
fail_count = 0;
low_soc_count = 0;
pos_err_count = 0;

addpath(genpath(pwd));
load_db_params;
```

```
conn = database(datasource_name, user_name, password);

% load UAV airframe
uav_sern = 'X001';
octomodel = get_airframe(conn, uav_sern);

% load battery
battery_sern = 'B001';
battery = get_battery(conn, battery_sern);
batterytwin = get_battery(conn, battery_sern);

% load motors
[Motor1, Motor2, Motor3, Motor4, Motor5, Motor6, Motor7, Motor8] = get_motors(conn, octomodel.i
[Motortwin1, Motortwin2, Motortwin3, Motortwin4, Motortwin5, Motortwin6, Motortwin7, Motortwin8

% initial rul estimate, used as baseline in rul updates where the minimum
% value is taken to ensure rul_hat never exceeds this value
rul_init = 18.0;
rul_hat = rul_init;

% minimum rul
rul_threshold = 10.0;

% load base directory
load_base_workspace;
```

Initialize some variables

```
% for poly fitting
lookback = 6;

% how far into the future to look
horizon = 2;

% number of missions (can be oversized)
n_missions = 250;

% keep track of delta over time
% number of missions, 3 degradation parameters, 2 coefficients to save
% (slope & intercept)
polys = zeros(n_missions, 3, 2);

% keep track of degradation parameter values for poly fitting
q_deg = zeros(n_missions, 1);
r_deg = zeros(n_missions, 1);
m_deg = zeros(n_missions, 1);

% variance gets tighter over time, a pseudo-hack...
r_var_vals = [.001:-.00001:.0001];
q_var_vals = [.9:-.01:.2];
m_var_vals = [.02:-.00025:.0025];

% keep track of rul
```

```
ruls = zeros(n_missions, 1);
```

Main Loop

```
% load initial trajectory, catch edge case that the first trajectory
% explores rather than exploits
load_trajectory;
while trajectory.path_time > rul_init
    load_trajectory;
end

for i = 68:n_missions
    if i < 20 && i >= 11
        lookback = 8;
        horizon = 3;
    elseif i >= 21 && i < 30
        lookback = 10;
        horizon = 4;
    elseif i >= 31
        lookback = 12;
        horizon = 6;
    end

    ruls(i) = rul_hat;

    % I don't think this should ever execute now that the digital twin is
    % selecting trajectories for the true system
    if end_sim == 1
        disp("[INFO] no more valid trajectories. ending simulation.")
        break;
    end
    if trajectory.path_time > rul_hat
        load_trajectory;
        while trajectory.path_time > rul_init
            load_trajectory;
        end
        %fprintf("[INFO] TrueSystem selecting trajectory: <%d> with path_time: %.2f to explore
        fprintf("[INFO] TrueSystem selecting trajectory: <%d> with path_time: %.2f that meets c
    end
    sys = "TrueSystem";
    octomodel.sampletime = true_sample_rate;
    fprintf('[INFO] simulating true system on i: %d\n', i)
    %tic
    sim('truesystem.slx');
    %toc
```

update degradation parameters for saving

- assign values from the current run to the arrays for saving

```
    q_deg(i) = battery.Q;
    r_deg(i) = battery.R0;
```

```
    m_deg(i) = Motor2.Req;
```

update variance

```
    fprintf('[INFO] updating degradation parameter variance on i: %d\n', i)
    if i <= length(r_var_vals)
       r_var = r_var_vals(i);
    else
        r_var = .0001;
    end
    if i <= length(q_var_vals)
        q_var = q_var_vals(i);
    else
        q_var = .25;
    end
    if i <= length(m_var_vals)
        m_var = m_var_vals(i);
    else
        m_var = .005;
    end
```

sample the degradation parameters and update

```
    fprintf('[INFO] updating degradation parameter values via random sampling on i: %d\n', i)
    battery.R0 = max(abs(normrnd(rdeg(i), r_var)), .0001);
    battery.Q = min(abs(normrnd(qdeg(i), q_var)), 15.5);
    Motor2.Req = max(abs(normrnd(mdeg(i), m_var)), .001);
```

write telemetry data to database

```
    distance = calculatedistance([pos_actual.Data(:,1) pos_actual.Data(:,2)]);
    mission_id = table2array(select(conn, 'select id from mission_tb mt order by id desc limit
    if isempty(mission_id)
        mission_id = 1;
    else
        mission_id = mission_id + 1;
    end
    start = table2array(select(conn, 'select mt.dt_stop from mission_tb mt order by dt_stop des
    if isempty(start)
        start = datetime(now, 'ConvertFrom', 'datenum');
    end
    start = datetime(start, 'InputFormat', 'yyyy-MM-dd HH:mm:ss');
    start = dateshift(start, 'start', 'second');
    start = start + hours(1);
    stop = start + seconds(flight_time.Data(end, 1)*60);

    fprintf("[INFO] i: %d\tmission_id: %d\trul_hat: %.2f\tflight_time: %.2f\tdistance: %.2f\tR0

    write_mission_data;
    write_battery_data;
    write_flight_data;

    if any(stop_code.Data(:,1)) == 1 && ~any(stop_code.Data(:,3)) == 1
        fprintf('[WARN] true system low soc threshold exceeded on i: %d\tmission_id: %d\n', i,
```

```
        %break;
    end

    if any(stop_code.Data(:,2)) == 1
        fprintf('[WARN] true system position error threshold exceeded on i: %d\tmission_id: %d\
        %break;
    end

    if any(stop_code.Data(:,3)) == 1
        fprintf('[INFO] success on i: %d\tmission_id: %d\n', i, mission_id)
    end

    clear('trajectory', 'battery_actual', 'battery_observed', 'ctrl_err', 'current', 'current_r
```

define placeholder variables

```
    twin_ctr = 1;
    twin_count = 4;
    times = zeros(1, twin_count);
    vs = zeros(1, twin_count);
    socs = zeros(1, twin_count);
    r0s = zeros(1, twin_count);
    qs = zeros(1, twin_count);
    ms = zeros(1, twin_count);
    dist = zeros(1, twin_count);
    errs = zeros(1, twin_count);
    degs = zeros(3, twin_count);
    codes = zeros(3, twin_count);
```

Update twin degradation parameters

```
    if i > lookback
        x = double(((i - (lookback-1)):1:i)');
        r_poly = polyfit(x, smoothdata(r_deg(x), 'rlowess', 5), 1);
        q_poly = polyfit(x, smoothdata(q_deg(x), 'rlowess', 5), 1);
        m_poly = polyfit(x, smoothdata(m_deg(x), 'rlowess', 5), 1);

        polys(i, 1, :) = r_poly;
        polys(i, 2, :) = q_poly;
        polys(i, 3, :) = m_poly;

        r_mu = polyval(r_poly, i + horizon);
        q_mu = polyval(q_poly, i + horizon);
        m_mu = polyval(m_poly, i + horizon);
        fprintf('[INFO] forecasting degradation values: r_mu: %.6f\tq_mu: %.6f\tm_mu: %.6f', r_
        batterytwin.R0 = max(abs(normrnd(r_mu, r_var)), .0001);
        batterytwin.Q = min(abs(normrnd(q_mu, q_var)), 15.5);
        Motortwin2.Req = max(abs(normrnd(m_mu, m_var)), .001);
    else
        batterytwin.R0 = max(abs(normrnd(rdeg(i), r_var)), .0001);
        batterytwin.Q = min(abs(normrnd(qdeg(i), q_var)), 15.5);
        Motortwin2.Req = max(abs(normrnd(mdeg(i), m_var)), .001);
    end
    fprintf("[INFO] digital twin degradation parameters: %.4f\t%.4f\t%.4f", batterytwin.R0, bat
```

```
    write_degradation_data;
```

now simulate digital twin

```
    updated = true;
    while updated
        load_trajectory;
        if(isempty(trajectory))
            disp("[INFO] no more valid trajectories. ending simulation.")
            break;
        end
        if trajectory.path_time > rul_hat
            fprintf("[INFO] DigitalTwin selecting trajectory: <%d> with path_time: %.2f to expl
        else
            fprintf("[INFO] DigitalTwin selecting trajectory: <%d> with path_time: %.2f that me
        end
        sys = "DigitalTwin";
        octomodel.sampletime = twin_sample_rate;
        for twin_ctr=1:twin_count
            fprintf('[INFO] simulating digital twin on i %d, mission_id: %d\n', i, mission_id)
            out = sim('digitaltwin1c.slx');
            %        get the output from each parallel worker
            times(twin_ctr) = flight_time.Data(end);
            vs(twin_ctr) = battery_actual.Data(end, 1);
            socs(twin_ctr) = battery_actual.Data(end, 2);
            r0s(twin_ctr) = battery_actual.Data(end, 3);
            qs(twin_ctr) = battery_actual.Data(end, 6);
            ms(twin_ctr) = motors.Data(end, 1);
            errs(twin_ctr) = mean(euclidean_pos_err);
            dist(twin_ctr) = calculatedistance([pos_actual.Data(:,1) pos_actual.Data(:,2)]);
            degs(:, twin_ctr) = [batterytwin.R0 batterytwin.Q Motortwin2.Req]';
            codes(:, twin_ctr) = [any(stop_code.Data(:,1)); any(stop_code.Data(:,2)); any(stop_
```

write digital twin parameters to db

```
            write_twin_params_data;
```

resample the degradation parameters for the next digital twin simulation

```
            if twin_count > 1 && twin_ctr < twin_count
               fprintf('[INFO] resampling for twin run # %d', twin_ctr + 1);
               if i > lookback
                    batterytwin.R0 = normrnd(r_mu, r_var);
                    batterytwin.Q = normrnd(q_mu, q_var);
                    Motortwin2.Req = normrnd(m_mu, m_var);
                else
                    batterytwin.R0 = max(abs(normrnd(rdeg(i), r_var)), .00075);
                    batterytwin.Q = min(abs(normrnd(qdeg(i), q_var)), 15.5);
                    Motortwin2.Req = max(abs(normrnd(mdeg(i), m_var)), .001);
                end
            end
            fprintf("[INFO] digital twin degradation parameters: %.4f\t%.4f\t%.4f", batterytwin
        end
```

```
        low_soc = sum(codes(1,:) == 1);
        pos_err = sum(codes(2,:) == 1);
        success = sum(codes(3,:) == 1);
        fprintf("[INFO] DigitalTwin mean parameter values: R0 = %.5f\t Q = %.2f\t Req = %.5f\n\
```

update rul

```
        if low_soc == 1
            fprintf('[WARN] DigitalTwin low soc threshold exceeded once, adjusting rul_hat')
            rul_hat = rul_hat - .5;
        end
        if pos_err == 1
            fprintf('[WARN] DigitalTwin pos err threshold exceeded once, adjusting rul_hat')
            rul_hat = rul_hat - 1.0;
        end

        if low_soc > 1
            fprintf('[WARN] DigitalTwin low soc threshold exceeded on i: %d\tmission_id: %d\n',
            temp = mean(times(:)) - 1;
            res = max(temp, rul_hat - 2);
            fprintf('[INFO] updating RUL from %.2f to %.2f', rul_hat, res)
            rul_hat = mean(times(:)) - 1; % rul is now 1 minute less than the digital twin flig
            updated = true;
        end

        if pos_err > 1
            fprintf('[WARN] DigitalTwin position error threshold exceeded on i: %d\tmission_id:
            temp = mean(times(:)) - 1;
            res = max(temp, rul_hat - 2);
            fprintf('[INFO] updating RUL from %.2f to %.2f', rul_hat, res)
            rul_hat = mean(times(:)) - 1; % rul is now 1 minute less than the digital twin flig
            updated = true;
        end

        if success >= 3 && pos_err < 2 && low_soc < 2
            fprintf('[INFO] digital twin mission success on i: %d\tmission_id: %d\n   trajector
            updated = false;
            if mean(times(:)) - 1 > rul_hat
                fprintf('[INFO] new RUL update is available, %.2f replaces %.2f\n', mean(times(
                rul_hat = mean(times(:)) - 1;
            end
        end
        if updated
            fprintf('[INFO] selecting new trajectory to repeat DigitalTwin simulation')
        end

        % otherwise, end of life was never reached so the current rul estimate
        % is the best estimate

        if rul_hat <= rul_threshold
            fail_count = fail_count + 1;
            fprintf('[INFO] digital twin rul_hat: %.2f does not meet the threshold: %.2f on i,m
            if fail_count == 10
                fprintf('[INFO] fail_count reached limit. Stopping simulation.')
```

```
                end_sim = 1;
                break;
            end
        end
        clear('battery_actual', 'battery_observed', 'ctrl_err', 'current', 'current_rs', 'eucli
    end
end
```

```
[INFO] simulating true system on i: 68
[INFO] updating degradation parameter variance on i: 68
[INFO] updating degradation parameter values via random sampling on i: 68
[INFO] i: 68 mission_id: 1162 rul_hat: 17.16 flight_time: 14.83 distance: 1083.70 R0: 0.00568 Q: 13.40 Req: 0.27748
[INFO] success on i: 68 mission_id: 1162
[INFO] forecasting degradation values: r_mu: 0.006289 q_mu: 13.369271 m_mu: 0.283584
[INFO] digital twin degradation parameters: 0.0067 13.1161 0.2829
[INFO] DigitalTwin selecting trajectory: <13> with path_time: 13.94 that meets constraint: path_time < 17.16
[INFO] simulating digital twin on i 68, mission_id: 1162
[INFO] resampling for twin run # 2
[INFO] digital twin degradation parameters: 0.0067 13.6323 0.2803
[INFO] simulating digital twin on i 68, mission_id: 1162
[INFO] resampling for twin run # 3
[INFO] digital twin degradation parameters: 0.0061 13.3458 0.2823
[INFO] simulating digital twin on i 68, mission_id: 1162
[INFO] resampling for twin run # 4
[INFO] digital twin degradation parameters: 0.0061 12.7886 0.2857
[INFO] simulating digital twin on i 68, mission_id: 1162
[INFO] digital twin degradation parameters: 0.0061 12.7886 0.2857
[INFO] DigitalTwin mean parameter values: R0 = 0.00638  Q = 13.22  Req = 0.28278
  stop code counts: low_soc: 0 pos_err: 0  success: 4
[INFO] digital twin mission success on i: 68 mission_id: 1162
   trajectory <13> selected for TrueSystem
[INFO] simulating true system on i: 69
[INFO] updating degradation parameter variance on i: 69
[INFO] updating degradation parameter values via random sampling on i: 69
[INFO] i: 69 mission_id: 1163 rul_hat: 17.16 flight_time: 13.94 distance: 1047.73 R0: 0.00580 Q: 13.78 Req: 0.27823
[INFO] success on i: 69 mission_id: 1163
[INFO] forecasting degradation values: r_mu: 0.006676 q_mu: 12.743576 m_mu: 0.289805
[INFO] digital twin degradation parameters: 0.0057 12.6773 0.2922
[INFO] DigitalTwin selecting trajectory: <6> with path_time: 18.81 to explore constraint boundary < 17.16
[INFO] simulating digital twin on i 69, mission_id: 1163
[INFO] resampling for twin run # 2
[INFO] digital twin degradation parameters: 0.0068 12.7959 0.2926
[INFO] simulating digital twin on i 69, mission_id: 1163
[INFO] resampling for twin run # 3
[INFO] digital twin degradation parameters: 0.0073 12.5431 0.2961
[INFO] simulating digital twin on i 69, mission_id: 1163
[INFO] resampling for twin run # 4
[INFO] digital twin degradation parameters: 0.0067 12.5678 0.2874
[INFO] simulating digital twin on i 69, mission_id: 1163
[INFO] digital twin degradation parameters: 0.0067 12.5678 0.2874
[INFO] DigitalTwin mean parameter values: R0 = 0.00665  Q = 12.65  Req = 0.29205
  stop code counts: low_soc: 4 pos_err: 0  success: 0
[WARN] DigitalTwin low soc threshold exceeded on i: 69 mission_id: 1163
[INFO] updating RUL from 17.16 to 15.85
[INFO] selecting new trajectory to repeat DigitalTwin simulation
[INFO] DigitalTwin selecting trajectory: <10> with path_time: 13.57 that meets constraint: path_time < 15.85
[INFO] simulating digital twin on i 69, mission_id: 1163
[INFO] resampling for twin run # 2
[INFO] digital twin degradation parameters: 0.0068 12.9255 0.2909
[INFO] simulating digital twin on i 69, mission_id: 1163
[INFO] resampling for twin run # 3
[INFO] digital twin degradation parameters: 0.0063 12.5917 0.2875
[INFO] simulating digital twin on i 69, mission_id: 1163
```

```
[INFO] resampling for twin run # 4
[INFO] digital twin degradation parameters: 0.0065 12.8217 0.2908
[INFO] simulating digital twin on i 69, mission_id: 1163
[INFO] digital twin degradation parameters: 0.0065 12.8217 0.2908
[INFO] DigitalTwin mean parameter values: R0 = 0.00660  Q = 12.73  Req = 0.28916
  stop code counts: low_soc: 0 pos_err: 0  success: 4
[INFO] digital twin mission success on i: 69 mission_id: 1163
   trajectory <10> selected for TrueSystem
[INFO] simulating true system on i: 70
[INFO] updating degradation parameter variance on i: 70
[INFO] updating degradation parameter values via random sampling on i: 70
[INFO] i: 70 mission_id: 1164 rul_hat: 15.85 flight_time: 13.58 distance: 1021.11 R0: 0.00606 Q: 13.39 Req: 0.27728
[INFO] success on i: 70 mission_id: 1164
[INFO] forecasting degradation values: r_mu: 0.007414 q_mu: 13.180539 m_mu: 0.287648
[INFO] digital twin degradation parameters: 0.0076 13.1533 0.2916
[INFO] DigitalTwin selecting trajectory: <10> with path_time: 13.57 that meets constraint: path_time < 15.85
[INFO] simulating digital twin on i 70, mission_id: 1164
[INFO] resampling for twin run # 2
[INFO] digital twin degradation parameters: 0.0078 12.9999 0.2875
[INFO] simulating digital twin on i 70, mission_id: 1164
[INFO] resampling for twin run # 3
[INFO] digital twin degradation parameters: 0.0070 12.9850 0.2837
[INFO] simulating digital twin on i 70, mission_id: 1164
[INFO] resampling for twin run # 4
[INFO] digital twin degradation parameters: 0.0071 13.2577 0.2870
[INFO] simulating digital twin on i 70, mission_id: 1164
[INFO] digital twin degradation parameters: 0.0071 13.2577 0.2870
[INFO] DigitalTwin mean parameter values: R0 = 0.00738  Q = 13.10  Req = 0.28744
  stop code counts: low_soc: 0 pos_err: 0  success: 4
[INFO] digital twin mission success on i: 70 mission_id: 1164
   trajectory <10> selected for TrueSystem
[INFO] simulating true system on i: 71
[INFO] updating degradation parameter variance on i: 71
[INFO] updating degradation parameter values via random sampling on i: 71
[INFO] i: 71 mission_id: 1165 rul_hat: 15.85 flight_time: 13.58 distance: 1021.09 R0: 0.00657 Q: 13.78 Req: 0.27984
[INFO] success on i: 71 mission_id: 1165
[INFO] forecasting degradation values: r_mu: 0.007397 q_mu: 13.178978 m_mu: 0.282530
[INFO] digital twin degradation parameters: 0.0076 13.3300 0.2884
[INFO] DigitalTwin selecting trajectory: <13> with path_time: 13.94 that meets constraint: path_time < 15.85
[INFO] simulating digital twin on i 71, mission_id: 1165
[INFO] resampling for twin run # 2
[INFO] digital twin degradation parameters: 0.0075 13.3125 0.2849
[INFO] simulating digital twin on i 71, mission_id: 1165
[INFO] resampling for twin run # 3
[INFO] digital twin degradation parameters: 0.0076 13.0806 0.2826
[INFO] simulating digital twin on i 71, mission_id: 1165
[INFO] resampling for twin run # 4
[INFO] digital twin degradation parameters: 0.0075 13.2221 0.2876
[INFO] simulating digital twin on i 71, mission_id: 1165
[INFO] digital twin degradation parameters: 0.0075 13.2221 0.2876
[INFO] DigitalTwin mean parameter values: R0 = 0.00756  Q = 13.24  Req = 0.28588
  stop code counts: low_soc: 0 pos_err: 0  success: 4
[INFO] digital twin mission success on i: 71 mission_id: 1165
   trajectory <13> selected for TrueSystem
[INFO] simulating true system on i: 72
[INFO] updating degradation parameter variance on i: 72
[INFO] updating degradation parameter values via random sampling on i: 72
[INFO] i: 72 mission_id: 1166 rul_hat: 15.85 flight_time: 13.94 distance: 1047.77 R0: 0.00621 Q: 13.75 Req: 0.28562
[INFO] success on i: 72 mission_id: 1166
[INFO] forecasting degradation values: r_mu: 0.007702 q_mu: 13.972775 m_mu: 0.284984
[INFO] digital twin degradation parameters: 0.0075 14.0967 0.2845
[INFO] DigitalTwin selecting trajectory: <10> with path_time: 13.57 that meets constraint: path_time < 15.85
[INFO] simulating digital twin on i 72, mission_id: 1166
[INFO] resampling for twin run # 2
[INFO] digital twin degradation parameters: 0.0082 13.8730 0.2881
```

```
[INFO] simulating digital twin on i 72, mission_id: 1166
[INFO] resampling for twin run # 3
[INFO] digital twin degradation parameters: 0.0074 13.7424 0.2788
[INFO] simulating digital twin on i 72, mission_id: 1166
[INFO] resampling for twin run # 4
[INFO] digital twin degradation parameters: 0.0073 13.7371 0.2805
[INFO] simulating digital twin on i 72, mission_id: 1166
[INFO] digital twin degradation parameters: 0.0073 13.7371 0.2805
[INFO] DigitalTwin mean parameter values: R0 = 0.00759  Q = 13.86  Req = 0.28298
  stop code counts: low_soc: 0 pos_err: 0  success: 4
[INFO] digital twin mission success on i: 72 mission_id: 1166
   trajectory <10> selected for TrueSystem
[INFO] simulating true system on i: 73
[INFO] updating degradation parameter variance on i: 73
[INFO] updating degradation parameter values via random sampling on i: 73
[INFO] i: 73 mission_id: 1167 rul_hat: 15.85 flight_time: 13.58 distance: 1021.16 R0: 0.00684 Q: 13.10 Req: 0.27791
[INFO] success on i: 73 mission_id: 1167
[INFO] forecasting degradation values: r_mu: 0.007668 q_mu: 13.734311 m_mu: 0.283393
[INFO] digital twin degradation parameters: 0.0075 13.5359 0.2818
[INFO] DigitalTwin selecting trajectory: <3> with path_time: 17.83 to explore constraint boundary < 15.85
[INFO] simulating digital twin on i 73, mission_id: 1167
[INFO] resampling for twin run # 2
[INFO] digital twin degradation parameters: 0.0078 14.1307 0.2868
[INFO] simulating digital twin on i 73, mission_id: 1167
[INFO] resampling for twin run # 3
[INFO] digital twin degradation parameters: 0.0077 14.0058 0.2945
[INFO] simulating digital twin on i 73, mission_id: 1167
[INFO] resampling for twin run # 4
[INFO] digital twin degradation parameters: 0.0075 13.9464 0.2793
[INFO] simulating digital twin on i 73, mission_id: 1167
[INFO] digital twin degradation parameters: 0.0075 13.9464 0.2793
[INFO] DigitalTwin mean parameter values: R0 = 0.00762  Q = 13.90  Req = 0.28562
  stop code counts: low_soc: 0 pos_err: 0  success: 4
[INFO] digital twin mission success on i: 73 mission_id: 1167
   trajectory <3> selected for TrueSystem
[INFO] new RUL update is available, 16.84 replaces 15.85
[INFO] TrueSystem selecting trajectory: <11> with path_time: 16.38 that meets constraint: path_time < 16.84
[INFO] simulating true system on i: 74
[INFO] updating degradation parameter variance on i: 74
[INFO] updating degradation parameter values via random sampling on i: 74
[INFO] i: 74 mission_id: 1168 rul_hat: 16.84 flight_time: 16.36 distance: 1218.88 R0: 0.00725 Q: 12.99 Req: 0.27322
[INFO] success on i: 74 mission_id: 1168
[INFO] forecasting degradation values: r_mu: 0.008055 q_mu: 13.204138 m_mu: 0.278838
[INFO] digital twin degradation parameters: 0.0080 13.3543 0.2828
[INFO] DigitalTwin selecting trajectory: <14> with path_time: 14.81 that meets constraint: path_time < 16.84
[INFO] simulating digital twin on i 74, mission_id: 1168
[INFO] resampling for twin run # 2
[INFO] digital twin degradation parameters: 0.0082 13.8274 0.2887
[INFO] simulating digital twin on i 74, mission_id: 1168
[INFO] resampling for twin run # 3
[INFO] digital twin degradation parameters: 0.0080 13.5577 0.2757
[INFO] simulating digital twin on i 74, mission_id: 1168
[INFO] resampling for twin run # 4
[INFO] digital twin degradation parameters: 0.0081 13.2402 0.2827
[INFO] simulating digital twin on i 74, mission_id: 1168
[INFO] digital twin degradation parameters: 0.0081 13.2402 0.2827
[INFO] DigitalTwin mean parameter values: R0 = 0.00811  Q = 13.49  Req = 0.28247
  stop code counts: low_soc: 0 pos_err: 0  success: 4
[INFO] digital twin mission success on i: 74 mission_id: 1168
   trajectory <14> selected for TrueSystem
[INFO] simulating true system on i: 75
[INFO] updating degradation parameter variance on i: 75
[INFO] updating degradation parameter values via random sampling on i: 75
[INFO] i: 75 mission_id: 1169 rul_hat: 16.84 flight_time: 14.83 distance: 1083.76 R0: 0.00728 Q: 13.60 Req: 0.28283
[INFO] success on i: 75 mission_id: 1169
```

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[INFO] forecasting degradation values: r_mu: 0.008634 q_mu: 12.708169 m_mu: 0.274693
[INFO] digital twin degradation parameters: 0.0087 12.4510 0.2727
[INFO] DigitalTwin selecting trajectory: <11> with path_time: 16.38 that meets constraint: path_time < 16.84
[INFO] simulating digital twin on i 75, mission_id: 1169
[INFO] resampling for twin run # 2
[INFO] digital twin degradation parameters: 0.0084 12.6208 0.2755
[INFO] simulating digital twin on i 75, mission_id: 1169
[INFO] resampling for twin run # 3
[INFO] digital twin degradation parameters: 0.0089 12.4409 0.2762
[INFO] simulating digital twin on i 75, mission_id: 1169
[INFO] resampling for twin run # 4
[INFO] digital twin degradation parameters: 0.0089 12.9485 0.2667
[INFO] simulating digital twin on i 75, mission_id: 1169
[INFO] digital twin degradation parameters: 0.0089 12.9485 0.2667
[INFO] DigitalTwin mean parameter values: R0 = 0.00872  Q = 12.62  Req = 0.27279
  stop code counts: low_soc: 0 pos_err: 0  success: 4
[INFO] digital twin mission success on i: 75 mission_id: 1169
   trajectory <11> selected for TrueSystem
[INFO] simulating true system on i: 76
[INFO] updating degradation parameter variance on i: 76
[INFO] updating degradation parameter values via random sampling on i: 76
[INFO] i: 76 mission_id: 1170 rul_hat: 16.84 flight_time: 16.36 distance: 1218.83 R0: 0.00812 Q: 13.37 Req: 0.28967
[INFO] success on i: 76 mission_id: 1170
[INFO] forecasting degradation values: r_mu: 0.008684 q_mu: 13.052622 m_mu: 0.281496
[INFO] digital twin degradation parameters: 0.0089 12.9654 0.2828
[INFO] DigitalTwin selecting trajectory: <6> with path_time: 18.81 to explore constraint boundary < 16.84
[INFO] simulating digital twin on i 76, mission_id: 1170
[INFO] resampling for twin run # 2
[INFO] digital twin degradation parameters: 0.0085 12.9538 0.2758
[INFO] simulating digital twin on i 76, mission_id: 1170
[INFO] resampling for twin run # 3
[INFO] digital twin degradation parameters: 0.0081 13.2626 0.2784
[INFO] simulating digital twin on i 76, mission_id: 1170
[INFO] resampling for twin run # 4
[INFO] digital twin degradation parameters: 0.0090 12.8131 0.2863
[INFO] simulating digital twin on i 76, mission_id: 1170
[INFO] digital twin degradation parameters: 0.0090 12.8131 0.2863
[INFO] DigitalTwin mean parameter values: R0 = 0.00864  Q = 13.00  Req = 0.28083
  stop code counts: low_soc: 4 pos_err: 0  success: 0
[WARN] DigitalTwin low soc threshold exceeded on i: 76 mission_id: 1170
[INFO] updating RUL from 16.84 to 16.45
[INFO] selecting new trajectory to repeat DigitalTwin simulation
[INFO] DigitalTwin selecting trajectory: <15> with path_time: 17.63 to explore constraint boundary < 16.45
[INFO] simulating digital twin on i 76, mission_id: 1170
[INFO] resampling for twin run # 2
[INFO] digital twin degradation parameters: 0.0084 13.0080 0.2791
[INFO] simulating digital twin on i 76, mission_id: 1170
[INFO] resampling for twin run # 3
[INFO] digital twin degradation parameters: 0.0084 12.9414 0.2734
[INFO] simulating digital twin on i 76, mission_id: 1170
[INFO] resampling for twin run # 4
[INFO] digital twin degradation parameters: 0.0086 13.0033 0.2773
[INFO] simulating digital twin on i 76, mission_id: 1170
[INFO] digital twin degradation parameters: 0.0086 13.0033 0.2773
[INFO] DigitalTwin mean parameter values: R0 = 0.00862  Q = 12.94  Req = 0.27903
  stop code counts: low_soc: 4 pos_err: 0  success: 0
[WARN] DigitalTwin low soc threshold exceeded on i: 76 mission_id: 1170
[INFO] updating RUL from 16.45 to 16.32
[INFO] selecting new trajectory to repeat DigitalTwin simulation
[INFO] DigitalTwin selecting trajectory: <14> with path_time: 14.81 that meets constraint: path_time < 16.32
[INFO] simulating digital twin on i 76, mission_id: 1170
[INFO] resampling for twin run # 2
[INFO] digital twin degradation parameters: 0.0086 13.1838 0.2826
[INFO] simulating digital twin on i 76, mission_id: 1170
[INFO] resampling for twin run # 3
```

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[INFO] digital twin degradation parameters: 0.0081 12.8595 0.2795
[INFO] simulating digital twin on i 76, mission_id: 1170
[INFO] resampling for twin run # 4
[INFO] digital twin degradation parameters: 0.0085 12.7144 0.2813
[INFO] simulating digital twin on i 76, mission_id: 1170
[INFO] digital twin degradation parameters: 0.0085 12.7144 0.2813
[INFO] DigitalTwin mean parameter values: R0 = 0.00847  Q = 12.94  Req = 0.28016
  stop code counts: low_soc: 0 pos_err: 0  success: 4
[INFO] digital twin mission success on i: 76 mission_id: 1170
   trajectory <14> selected for TrueSystem
[INFO] simulating true system on i: 77
[INFO] updating degradation parameter variance on i: 77
[INFO] updating degradation parameter values via random sampling on i: 77
[INFO] i: 77 mission_id: 1171 rul_hat: 16.32 flight_time: 14.83 distance: 1083.84 R0: 0.00826 Q: 13.65 Req: 0.28411
[INFO] success on i: 77 mission_id: 1171
[INFO] forecasting degradation values: r_mu: 0.009869 q_mu: 13.053545 m_mu: 0.286311
[INFO] digital twin degradation parameters: 0.0100 13.0209 0.2772
[INFO] DigitalTwin selecting trajectory: <14> with path_time: 14.81 that meets constraint: path_time < 16.32
[INFO] simulating digital twin on i 77, mission_id: 1171
[INFO] resampling for twin run # 2
[INFO] digital twin degradation parameters: 0.0098 13.1976 0.2821
[INFO] simulating digital twin on i 77, mission_id: 1171
[INFO] resampling for twin run # 3
[INFO] digital twin degradation parameters: 0.0097 13.1175 0.2835
[INFO] simulating digital twin on i 77, mission_id: 1171
[INFO] resampling for twin run # 4
[INFO] digital twin degradation parameters: 0.0096 12.9150 0.2829
[INFO] simulating digital twin on i 77, mission_id: 1171
[INFO] digital twin degradation parameters: 0.0096 12.9150 0.2829
[INFO] DigitalTwin mean parameter values: R0 = 0.00977  Q = 13.06  Req = 0.28143
  stop code counts: low_soc: 0 pos_err: 0  success: 4
[INFO] digital twin mission success on i: 77 mission_id: 1171
   trajectory <14> selected for TrueSystem
[INFO] simulating true system on i: 78
[INFO] updating degradation parameter variance on i: 78
[INFO] updating degradation parameter values via random sampling on i: 78
[INFO] i: 78 mission_id: 1172 rul_hat: 16.32 flight_time: 14.83 distance: 1083.88 R0: 0.00884 Q: 13.35 Req: 0.28706
[INFO] success on i: 78 mission_id: 1172
[INFO] forecasting degradation values: r_mu: 0.009824 q_mu: 13.231479 m_mu: 0.289852
[INFO] digital twin degradation parameters: 0.0097 13.7607 0.2904
[INFO] DigitalTwin selecting trajectory: <14> with path_time: 14.81 that meets constraint: path_time < 16.32
[INFO] simulating digital twin on i 78, mission_id: 1172
[INFO] resampling for twin run # 2
[INFO] digital twin degradation parameters: 0.0098 13.1298 0.2831
[INFO] simulating digital twin on i 78, mission_id: 1172
[INFO] resampling for twin run # 3
[INFO] digital twin degradation parameters: 0.0097 12.8245 0.2933
[INFO] simulating digital twin on i 78, mission_id: 1172
[INFO] resampling for twin run # 4
[INFO] digital twin degradation parameters: 0.0103 13.4165 0.2882
[INFO] simulating digital twin on i 78, mission_id: 1172
[INFO] digital twin degradation parameters: 0.0103 13.4165 0.2882
[INFO] DigitalTwin mean parameter values: R0 = 0.00989  Q = 13.28  Req = 0.28875
  stop code counts: low_soc: 0 pos_err: 0  success: 4
[INFO] digital twin mission success on i: 78 mission_id: 1172
   trajectory <14> selected for TrueSystem
[INFO] simulating true system on i: 79
[INFO] updating degradation parameter variance on i: 79
[INFO] updating degradation parameter values via random sampling on i: 79
[INFO] i: 79 mission_id: 1173 rul_hat: 16.32 flight_time: 14.83 distance: 1083.89 R0: 0.00937 Q: 13.34 Req: 0.27403
[INFO] success on i: 79 mission_id: 1173
[INFO] forecasting degradation values: r_mu: 0.010330 q_mu: 13.211559 m_mu: 0.289556
[INFO] digital twin degradation parameters: 0.0103 13.2312 0.2924
[INFO] DigitalTwin selecting trajectory: <9> with path_time: 13.45 that meets constraint: path_time < 16.32
[INFO] simulating digital twin on i 79, mission_id: 1173
```

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[INFO] resampling for twin run # 2
[INFO] digital twin degradation parameters: 0.0100 13.8264 0.2963
[INFO] simulating digital twin on i 79, mission_id: 1173
[INFO] resampling for twin run # 3
[INFO] digital twin degradation parameters: 0.0103 13.2836 0.2852
[INFO] simulating digital twin on i 79, mission_id: 1173
[INFO] resampling for twin run # 4
[INFO] digital twin degradation parameters: 0.0101 13.2306 0.2945
[INFO] simulating digital twin on i 79, mission_id: 1173
[INFO] digital twin degradation parameters: 0.0101 13.2306 0.2945
[INFO] DigitalTwin mean parameter values: R0 = 0.01018  Q = 13.39  Req = 0.29209
  stop code counts: low_soc: 0 pos_err: 0  success: 4
[INFO] digital twin mission success on i: 79 mission_id: 1173
   trajectory <9> selected for TrueSystem
[INFO] simulating true system on i: 80
[INFO] updating degradation parameter variance on i: 80
[INFO] updating degradation parameter values via random sampling on i: 80
[INFO] i: 80 mission_id: 1174 rul_hat: 16.32 flight_time: 13.47 distance: 994.71 R0: 0.00969 Q: 13.76 Req: 0.28430
[INFO] success on i: 80 mission_id: 1174
[INFO] forecasting degradation values: r_mu: 0.011030 q_mu: 13.238839 m_mu: 0.281118
[INFO] digital twin degradation parameters: 0.0110 12.5553 0.2796
[INFO] DigitalTwin selecting trajectory: <10> with path_time: 13.57 that meets constraint: path_time < 16.32
[INFO] simulating digital twin on i 80, mission_id: 1174
[INFO] resampling for twin run # 2
[INFO] digital twin degradation parameters: 0.0109 12.9170 0.2791
[INFO] simulating digital twin on i 80, mission_id: 1174
[INFO] resampling for twin run # 3
[INFO] digital twin degradation parameters: 0.0115 13.0066 0.2811
[INFO] simulating digital twin on i 80, mission_id: 1174
[INFO] resampling for twin run # 4
[INFO] digital twin degradation parameters: 0.0108 13.5300 0.2850
[INFO] simulating digital twin on i 80, mission_id: 1174
[INFO] digital twin degradation parameters: 0.0108 13.5300 0.2850
[INFO] DigitalTwin mean parameter values: R0 = 0.01104  Q = 13.00  Req = 0.28120
  stop code counts: low_soc: 0 pos_err: 0  success: 4
[INFO] digital twin mission success on i: 80 mission_id: 1174
   trajectory <10> selected for TrueSystem
[INFO] simulating true system on i: 81
[INFO] updating degradation parameter variance on i: 81
[INFO] updating degradation parameter values via random sampling on i: 81
[INFO] i: 81 mission_id: 1175 rul_hat: 16.32 flight_time: 13.58 distance: 1021.11 R0: 0.00996 Q: 13.18 Req: 0.29413
[INFO] success on i: 81 mission_id: 1175
[INFO] forecasting degradation values: r_mu: 0.011645 q_mu: 13.393893 m_mu: 0.290914
[INFO] digital twin degradation parameters: 0.0118 13.3930 0.2916
[INFO] DigitalTwin selecting trajectory: <15> with path_time: 17.63 to explore constraint boundary < 16.32
[INFO] simulating digital twin on i 81, mission_id: 1175
[INFO] resampling for twin run # 2
[INFO] digital twin degradation parameters: 0.0117 13.5360 0.2904
[INFO] simulating digital twin on i 81, mission_id: 1175
[INFO] resampling for twin run # 3
[INFO] digital twin degradation parameters: 0.0114 13.4858 0.2828
[INFO] simulating digital twin on i 81, mission_id: 1175
[INFO] resampling for twin run # 4
[INFO] digital twin degradation parameters: 0.0115 13.6584 0.2874
[INFO] simulating digital twin on i 81, mission_id: 1175
[INFO] digital twin degradation parameters: 0.0115 13.6584 0.2874
[INFO] DigitalTwin mean parameter values: R0 = 0.01160  Q = 13.52  Req = 0.28807
  stop code counts: low_soc: 0 pos_err: 0  success: 4
[INFO] digital twin mission success on i: 81 mission_id: 1175
   trajectory <15> selected for TrueSystem
[INFO] new RUL update is available, 16.63 replaces 16.32
[INFO] TrueSystem selecting trajectory: <14> with path_time: 14.81 that meets constraint: path_time < 16.63
[INFO] simulating true system on i: 82
[INFO] updating degradation parameter variance on i: 82
[INFO] updating degradation parameter values via random sampling on i: 82
```

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[INFO] i: 82 mission_id: 1176 rul_hat: 16.63 flight_time: 14.83 distance: 1083.87 R0: 0.01045 Q: 13.27 Req: 0.28505
[INFO] success on i: 82 mission_id: 1176
[INFO] forecasting degradation values: r_mu: 0.012093 q_mu: 13.314727 m_mu: 0.294197
[INFO] digital twin degradation parameters: 0.0117 13.5700 0.2914
[INFO] DigitalTwin selecting trajectory: <10> with path_time: 13.57 that meets constraint: path_time < 16.63
[INFO] simulating digital twin on i 82, mission_id: 1176
[INFO] resampling for twin run # 2
[INFO] digital twin degradation parameters: 0.0119 13.6288 0.2979
[INFO] simulating digital twin on i 82, mission_id: 1176
[INFO] resampling for twin run # 3
[INFO] digital twin degradation parameters: 0.0121 13.2250 0.3002
[INFO] simulating digital twin on i 82, mission_id: 1176
[INFO] resampling for twin run # 4
[INFO] digital twin degradation parameters: 0.0122 13.4478 0.3077
[INFO] simulating digital twin on i 82, mission_id: 1176
[INFO] digital twin degradation parameters: 0.0122 13.4478 0.3077
[INFO] DigitalTwin mean parameter values: R0 = 0.01197  Q = 13.47  Req = 0.29930
  stop code counts: low_soc: 0 pos_err: 0  success: 4
[INFO] digital twin mission success on i: 82 mission_id: 1176
   trajectory <10> selected for TrueSystem
[INFO] simulating true system on i: 83
[INFO] updating degradation parameter variance on i: 83
[INFO] updating degradation parameter values via random sampling on i: 83
[INFO] i: 83 mission_id: 1177 rul_hat: 16.63 flight_time: 13.58 distance: 1021.15 R0: 0.01098 Q: 13.42 Req: 0.28812
[INFO] success on i: 83 mission_id: 1177
[INFO] forecasting degradation values: r_mu: 0.012583 q_mu: 13.188602 m_mu: 0.290498
[INFO] digital twin degradation parameters: 0.0129 13.1648 0.2855
[INFO] DigitalTwin selecting trajectory: <11> with path_time: 16.38 that meets constraint: path_time < 16.63
[INFO] simulating digital twin on i 83, mission_id: 1177
[INFO] resampling for twin run # 2
[INFO] digital twin degradation parameters: 0.0128 12.8926 0.2919
[INFO] simulating digital twin on i 83, mission_id: 1177
[INFO] resampling for twin run # 3
[INFO] digital twin degradation parameters: 0.0127 13.3093 0.2924
[INFO] simulating digital twin on i 83, mission_id: 1177
[INFO] resampling for twin run # 4
[INFO] digital twin degradation parameters: 0.0124 13.1748 0.2951
[INFO] simulating digital twin on i 83, mission_id: 1177
[INFO] digital twin degradation parameters: 0.0124 13.1748 0.2951
[INFO] DigitalTwin mean parameter values: R0 = 0.01272  Q = 13.14  Req = 0.29124
  stop code counts: low_soc: 0 pos_err: 0  success: 4
[INFO] digital twin mission success on i: 83 mission_id: 1177
   trajectory <11> selected for TrueSystem
[INFO] simulating true system on i: 84
[INFO] updating degradation parameter variance on i: 84
[INFO] updating degradation parameter values via random sampling on i: 84
[INFO] i: 84 mission_id: 1178 rul_hat: 16.63 flight_time: 16.36 distance: 1218.88 R0: 0.01126 Q: 12.78 Req: 0.28570
[INFO] success on i: 84 mission_id: 1178
[INFO] forecasting degradation values: r_mu: 0.013415 q_mu: 13.364717 m_mu: 0.291281
[INFO] digital twin degradation parameters: 0.0136 13.2961 0.2924
[INFO] DigitalTwin selecting trajectory: <11> with path_time: 16.38 that meets constraint: path_time < 16.63
[INFO] simulating digital twin on i 84, mission_id: 1178
[INFO] resampling for twin run # 2
[INFO] digital twin degradation parameters: 0.0133 13.0482 0.2972
[INFO] simulating digital twin on i 84, mission_id: 1178
[INFO] resampling for twin run # 3
[INFO] digital twin degradation parameters: 0.0136 12.9729 0.2925
[INFO] simulating digital twin on i 84, mission_id: 1178
[INFO] resampling for twin run # 4
[INFO] digital twin degradation parameters: 0.0133 13.3233 0.2915
[INFO] simulating digital twin on i 84, mission_id: 1178
[INFO] digital twin degradation parameters: 0.0133 13.3233 0.2915
[INFO] DigitalTwin mean parameter values: R0 = 0.01343  Q = 13.16  Req = 0.29340
  stop code counts: low_soc: 0 pos_err: 0  success: 4
[INFO] digital twin mission success on i: 84 mission_id: 1178
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   trajectory <11> selected for TrueSystem
[INFO] simulating true system on i: 85
[INFO] updating degradation parameter variance on i: 85
[INFO] updating degradation parameter values via random sampling on i: 85
[INFO] i: 85 mission_id: 1179 rul_hat: 16.63 flight_time: 16.36 distance: 1218.91 R0: 0.01220 Q: 13.15 Req: 0.28675
[INFO] success on i: 85 mission_id: 1179
[INFO] forecasting degradation values: r_mu: 0.013663 q_mu: 13.186367 m_mu: 0.293535
[INFO] digital twin degradation parameters: 0.0138 13.4054 0.2942
[INFO] DigitalTwin selecting trajectory: <3> with path_time: 17.83 to explore constraint boundary < 16.63
[INFO] simulating digital twin on i 85, mission_id: 1179
[INFO] resampling for twin run # 2
[INFO] digital twin degradation parameters: 0.0136 13.3229 0.2870
[INFO] simulating digital twin on i 85, mission_id: 1179
[INFO] resampling for twin run # 3
[INFO] digital twin degradation parameters: 0.0136 13.0513 0.3004
[INFO] simulating digital twin on i 85, mission_id: 1179
[INFO] resampling for twin run # 4
[INFO] digital twin degradation parameters: 0.0138 13.3383 0.2981
[INFO] simulating digital twin on i 85, mission_id: 1179
[INFO] digital twin degradation parameters: 0.0138 13.3383 0.2981
[INFO] DigitalTwin mean parameter values: R0 = 0.01369  Q = 13.28  Req = 0.29494
  stop code counts: low_soc: 1 pos_err: 0  success: 3
[WARN] DigitalTwin low soc threshold exceeded once, adjusting rul_hat
[INFO] digital twin mission success on i: 85 mission_id: 1179
   trajectory <3> selected for TrueSystem
[INFO] new RUL update is available, 16.74 replaces 16.13
[INFO] TrueSystem selecting trajectory: <15> with path_time: 17.63 that meets constraint: path_time < 16.74
[INFO] simulating true system on i: 86
[INFO] updating degradation parameter variance on i: 86
[INFO] updating degradation parameter values via random sampling on i: 86
[INFO] i: 86 mission_id: 1180 rul_hat: 16.74 flight_time: 17.37 distance: 1263.30 R0: 0.01227 Q: 12.60 Req: 0.29106
[WARN] true system low soc threshold exceeded on i: 86 mission_id: 1180
[INFO] forecasting degradation values: r_mu: 0.014511 q_mu: 13.071570 m_mu: 0.292759
[INFO] digital twin degradation parameters: 0.0148 13.2793 0.2980
[INFO] DigitalTwin selecting trajectory: <3> with path_time: 17.83 to explore constraint boundary < 16.74
[INFO] simulating digital twin on i 86, mission_id: 1180
[INFO] resampling for twin run # 2
[INFO] digital twin degradation parameters: 0.0144 13.3470 0.2892
[INFO] simulating digital twin on i 86, mission_id: 1180
[INFO] resampling for twin run # 3
[INFO] digital twin degradation parameters: 0.0148 13.2942 0.2896
[INFO] simulating digital twin on i 86, mission_id: 1180
[INFO] resampling for twin run # 4
[INFO] digital twin degradation parameters: 0.0145 13.2020 0.2963
[INFO] simulating digital twin on i 86, mission_id: 1180
[INFO] digital twin degradation parameters: 0.0145 13.2020 0.2963
[INFO] DigitalTwin mean parameter values: R0 = 0.01462  Q = 13.28  Req = 0.29327
  stop code counts: low_soc: 1 pos_err: 0  success: 3
[WARN] DigitalTwin low soc threshold exceeded once, adjusting rul_hat
[INFO] digital twin mission success on i: 86 mission_id: 1180
   trajectory <3> selected for TrueSystem
[INFO] new RUL update is available, 16.81 replaces 16.24
[INFO] TrueSystem selecting trajectory: <15> with path_time: 17.63 that meets constraint: path_time < 16.81
[INFO] simulating true system on i: 87
[INFO] updating degradation parameter variance on i: 87
[INFO] updating degradation parameter values via random sampling on i: 87
[INFO] i: 87 mission_id: 1181 rul_hat: 16.81 flight_time: 16.67 distance: 1197.50 R0: 0.01294 Q: 13.01 Req: 0.28403
[WARN] true system low soc threshold exceeded on i: 87 mission_id: 1181
[INFO] forecasting degradation values: r_mu: 0.014886 q_mu: 12.487165 m_mu: 0.290317
[INFO] digital twin degradation parameters: 0.0150 12.6302 0.2911
[INFO] DigitalTwin selecting trajectory: <13> with path_time: 13.94 that meets constraint: path_time < 16.81
[INFO] simulating digital twin on i 87, mission_id: 1181
[INFO] resampling for twin run # 2
[INFO] digital twin degradation parameters: 0.0150 12.3092 0.2836
[INFO] simulating digital twin on i 87, mission_id: 1181
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[INFO] resampling for twin run # 3
[INFO] digital twin degradation parameters: 0.0150 12.6393 0.2905
[INFO] simulating digital twin on i 87, mission_id: 1181
[INFO] resampling for twin run # 4
[INFO] digital twin degradation parameters: 0.0149 12.6615 0.2882
[INFO] simulating digital twin on i 87, mission_id: 1181
[INFO] digital twin degradation parameters: 0.0149 12.6615 0.2882
[INFO] DigitalTwin mean parameter values: R0 = 0.01498  Q = 12.56  Req = 0.28834
  stop code counts: low_soc: 0 pos_err: 0  success: 4
[INFO] digital twin mission success on i: 87 mission_id: 1181
   trajectory <13> selected for TrueSystem
[INFO] simulating true system on i: 88
[INFO] updating degradation parameter variance on i: 88
[INFO] updating degradation parameter values via random sampling on i: 88
[INFO] i: 88 mission_id: 1182 rul_hat: 16.81 flight_time: 13.94 distance: 1047.84 R0: 0.01390 Q: 13.03 Req: 0.28873
[INFO] success on i: 88 mission_id: 1182
[INFO] forecasting degradation values: r_mu: 0.015266 q_mu: 12.516767 m_mu: 0.287084
[INFO] digital twin degradation parameters: 0.0152 12.8929 0.2838
[INFO] DigitalTwin selecting trajectory: <10> with path_time: 13.57 that meets constraint: path_time < 16.81
[INFO] simulating digital twin on i 88, mission_id: 1182
[INFO] resampling for twin run # 2
[INFO] digital twin degradation parameters: 0.0153 13.0676 0.2857
[INFO] simulating digital twin on i 88, mission_id: 1182
[INFO] resampling for twin run # 3
[INFO] digital twin degradation parameters: 0.0153 12.5119 0.2892
[INFO] simulating digital twin on i 88, mission_id: 1182
[INFO] resampling for twin run # 4
[INFO] digital twin degradation parameters: 0.0151 12.5792 0.2909
[INFO] simulating digital twin on i 88, mission_id: 1182
[INFO] digital twin degradation parameters: 0.0151 12.5792 0.2909
[INFO] DigitalTwin mean parameter values: R0 = 0.01523  Q = 12.76  Req = 0.28743
  stop code counts: low_soc: 0 pos_err: 0  success: 4
[INFO] digital twin mission success on i: 88 mission_id: 1182
   trajectory <10> selected for TrueSystem
[INFO] simulating true system on i: 89
[INFO] updating degradation parameter variance on i: 89
[INFO] updating degradation parameter values via random sampling on i: 89
[INFO] i: 89 mission_id: 1183 rul_hat: 16.81 flight_time: 13.58 distance: 1021.22 R0: 0.01436 Q: 12.82 Req: 0.29355
[INFO] success on i: 89 mission_id: 1183
[INFO] forecasting degradation values: r_mu: 0.016239 q_mu: 12.478059 m_mu: 0.290523
[INFO] digital twin degradation parameters: 0.0160 12.7885 0.2922
[INFO] DigitalTwin selecting trajectory: <13> with path_time: 13.94 that meets constraint: path_time < 16.81
[INFO] simulating digital twin on i 89, mission_id: 1183
[INFO] resampling for twin run # 2
[INFO] digital twin degradation parameters: 0.0163 12.8326 0.2849
[INFO] simulating digital twin on i 89, mission_id: 1183
[INFO] resampling for twin run # 3
[INFO] digital twin degradation parameters: 0.0162 12.7491 0.2905
[INFO] simulating digital twin on i 89, mission_id: 1183
[INFO] resampling for twin run # 4
[INFO] digital twin degradation parameters: 0.0163 12.0731 0.2923
[INFO] simulating digital twin on i 89, mission_id: 1183
[INFO] digital twin degradation parameters: 0.0163 12.0731 0.2923
[INFO] DigitalTwin mean parameter values: R0 = 0.01620  Q = 12.61  Req = 0.28997
  stop code counts: low_soc: 0 pos_err: 0  success: 4
[INFO] digital twin mission success on i: 89 mission_id: 1183
   trajectory <13> selected for TrueSystem
[INFO] simulating true system on i: 90
[INFO] updating degradation parameter variance on i: 90
[INFO] updating degradation parameter values via random sampling on i: 90
[INFO] i: 90 mission_id: 1184 rul_hat: 16.81 flight_time: 13.94 distance: 1047.79 R0: 0.01516 Q: 12.31 Req: 0.29311
[INFO] success on i: 90 mission_id: 1184
[INFO] forecasting degradation values: r_mu: 0.016956 q_mu: 12.456996 m_mu: 0.292986
[INFO] digital twin degradation parameters: 0.0168 12.1994 0.2960
[INFO] DigitalTwin selecting trajectory: <3> with path_time: 17.83 to explore constraint boundary < 16.81
```

```
[INFO] simulating digital twin on i 90, mission_id: 1184
[INFO] resampling for twin run # 2
[INFO] digital twin degradation parameters: 0.0169 12.9076 0.2926
[INFO] simulating digital twin on i 90, mission_id: 1184
[INFO] resampling for twin run # 3
[INFO] digital twin degradation parameters: 0.0170 12.3700 0.2955
[INFO] simulating digital twin on i 90, mission_id: 1184
[INFO] resampling for twin run # 4
[INFO] digital twin degradation parameters: 0.0168 12.4624 0.2886
[INFO] simulating digital twin on i 90, mission_id: 1184
[INFO] digital twin degradation parameters: 0.0168 12.4624 0.2886
[INFO] DigitalTwin mean parameter values: R0 = 0.01688  Q = 12.48  Req = 0.29315
  stop code counts: low_soc: 4 pos_err: 0  success: 0
[WARN] DigitalTwin low soc threshold exceeded on i: 90 mission_id: 1184
[INFO] updating RUL from 16.81 to 15.79
[INFO] selecting new trajectory to repeat DigitalTwin simulation
[INFO] DigitalTwin selecting trajectory: <9> with path_time: 13.45 that meets constraint: path_time < 15.79
[INFO] simulating digital twin on i 90, mission_id: 1184
[INFO] resampling for twin run # 2
[INFO] digital twin degradation parameters: 0.0172 12.3440 0.2957
[INFO] simulating digital twin on i 90, mission_id: 1184
[INFO] resampling for twin run # 3
[INFO] digital twin degradation parameters: 0.0169 12.4794 0.3069
[INFO] simulating digital twin on i 90, mission_id: 1184
[INFO] resampling for twin run # 4
[INFO] digital twin degradation parameters: 0.0170 12.3078 0.2980
[INFO] simulating digital twin on i 90, mission_id: 1184
[INFO] digital twin degradation parameters: 0.0170 12.3078 0.2980
[INFO] DigitalTwin mean parameter values: R0 = 0.01697  Q = 12.40  Req = 0.29728
  stop code counts: low_soc: 0 pos_err: 0  success: 4
[INFO] digital twin mission success on i: 90 mission_id: 1184
   trajectory <9> selected for TrueSystem
[INFO] simulating true system on i: 91
[INFO] updating degradation parameter variance on i: 91
[INFO] updating degradation parameter values via random sampling on i: 91
[INFO] i: 91 mission_id: 1185 rul_hat: 15.79 flight_time: 13.47 distance: 994.79 R0: 0.01586 Q: 12.45 Req: 0.29196
[INFO] success on i: 91 mission_id: 1185
[INFO] forecasting degradation values: r_mu: 0.017883 q_mu: 12.072974 m_mu: 0.299252
[INFO] digital twin degradation parameters: 0.0178 12.0096 0.2998
[INFO] DigitalTwin selecting trajectory: <9> with path_time: 13.45 that meets constraint: path_time < 15.79
[INFO] simulating digital twin on i 91, mission_id: 1185
[INFO] resampling for twin run # 2
[INFO] digital twin degradation parameters: 0.0179 11.8623 0.3011
[INFO] simulating digital twin on i 91, mission_id: 1185
[INFO] resampling for twin run # 3
[INFO] digital twin degradation parameters: 0.0178 12.2792 0.2982
[INFO] simulating digital twin on i 91, mission_id: 1185
[INFO] resampling for twin run # 4
[INFO] digital twin degradation parameters: 0.0180 11.8246 0.3032
[INFO] simulating digital twin on i 91, mission_id: 1185
[INFO] digital twin degradation parameters: 0.0180 11.8246 0.3032
[INFO] DigitalTwin mean parameter values: R0 = 0.01787  Q = 11.99  Req = 0.30056
  stop code counts: low_soc: 0 pos_err: 0  success: 4
[INFO] digital twin mission success on i: 91 mission_id: 1185
   trajectory <9> selected for TrueSystem
[INFO] simulating true system on i: 92
[INFO] updating degradation parameter variance on i: 92
[INFO] updating degradation parameter values via random sampling on i: 92
[INFO] i: 92 mission_id: 1186 rul_hat: 15.79 flight_time: 13.47 distance: 994.81 R0: 0.01650 Q: 12.77 Req: 0.29468
[INFO] success on i: 92 mission_id: 1186
[INFO] forecasting degradation values: r_mu: 0.018919 q_mu: 11.871398 m_mu: 0.297694
[INFO] digital twin degradation parameters: 0.0190 12.3221 0.3022
[INFO] DigitalTwin selecting trajectory: <14> with path_time: 14.81 that meets constraint: path_time < 15.79
[INFO] simulating digital twin on i 92, mission_id: 1186
[INFO] resampling for twin run # 2
```

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[INFO] digital twin degradation parameters: 0.0189 11.6220 0.2973
[INFO] simulating digital twin on i 92, mission_id: 1186
[INFO] resampling for twin run # 3
[INFO] digital twin degradation parameters: 0.0190 11.8495 0.3037
[INFO] simulating digital twin on i 92, mission_id: 1186
[INFO] resampling for twin run # 4
[INFO] digital twin degradation parameters: 0.0189 11.9808 0.2993
[INFO] simulating digital twin on i 92, mission_id: 1186
[INFO] digital twin degradation parameters: 0.0189 11.9808 0.2993
[INFO] DigitalTwin mean parameter values: R0 = 0.01895  Q = 11.94  Req = 0.30061
  stop code counts: low_soc: 0 pos_err: 0  success: 4
[INFO] digital twin mission success on i: 92 mission_id: 1186
   trajectory <14> selected for TrueSystem
[INFO] simulating true system on i: 93
[INFO] updating degradation parameter variance on i: 93
[INFO] updating degradation parameter values via random sampling on i: 93
[INFO] i: 93 mission_id: 1187 rul_hat: 15.79 flight_time: 14.83 distance: 1083.88 R0: 0.01719 Q: 12.62 Req: 0.30195
[INFO] success on i: 93 mission_id: 1187
[INFO] forecasting degradation values: r_mu: 0.019884 q_mu: 12.160645 m_mu: 0.293807
[INFO] digital twin degradation parameters: 0.0198 12.1223 0.2889
[INFO] DigitalTwin selecting trajectory: <13> with path_time: 13.94 that meets constraint: path_time < 15.79
[INFO] simulating digital twin on i 93, mission_id: 1187
[INFO] resampling for twin run # 2
[INFO] digital twin degradation parameters: 0.0200 12.1623 0.2957
[INFO] simulating digital twin on i 93, mission_id: 1187
[INFO] resampling for twin run # 3
[INFO] digital twin degradation parameters: 0.0198 12.1295 0.2980
[INFO] simulating digital twin on i 93, mission_id: 1187
[INFO] resampling for twin run # 4
[INFO] digital twin degradation parameters: 0.0198 11.9710 0.2989
[INFO] simulating digital twin on i 93, mission_id: 1187
[INFO] digital twin degradation parameters: 0.0198 11.9710 0.2989
[INFO] DigitalTwin mean parameter values: R0 = 0.01983  Q = 12.10  Req = 0.29538
  stop code counts: low_soc: 0 pos_err: 0  success: 4
[INFO] digital twin mission success on i: 93 mission_id: 1187
   trajectory <13> selected for TrueSystem
[INFO] simulating true system on i: 94
[INFO] updating degradation parameter variance on i: 94
[INFO] updating degradation parameter values via random sampling on i: 94
[INFO] i: 94 mission_id: 1188 rul_hat: 15.79 flight_time: 13.94 distance: 1047.82 R0: 0.01834 Q: 12.44 Req: 0.30001
[INFO] success on i: 94 mission_id: 1188
[INFO] forecasting degradation values: r_mu: 0.020775 q_mu: 12.104185 m_mu: 0.304206
[INFO] digital twin degradation parameters: 0.0206 12.2686 0.3049
[INFO] DigitalTwin selecting trajectory: <9> with path_time: 13.45 that meets constraint: path_time < 15.79
[INFO] simulating digital twin on i 94, mission_id: 1188
[INFO] resampling for twin run # 2
[INFO] digital twin degradation parameters: 0.0209 12.0648 0.2997
[INFO] simulating digital twin on i 94, mission_id: 1188
[INFO] resampling for twin run # 3
[INFO] digital twin degradation parameters: 0.0207 11.7937 0.3062
[INFO] simulating digital twin on i 94, mission_id: 1188
[INFO] resampling for twin run # 4
[INFO] digital twin degradation parameters: 0.0208 11.9083 0.3080
[INFO] simulating digital twin on i 94, mission_id: 1188
[INFO] digital twin degradation parameters: 0.0208 11.9083 0.3080
[INFO] DigitalTwin mean parameter values: R0 = 0.02076  Q = 12.01  Req = 0.30469
  stop code counts: low_soc: 0 pos_err: 0  success: 4
[INFO] digital twin mission success on i: 94 mission_id: 1188
   trajectory <9> selected for TrueSystem
[INFO] simulating true system on i: 95
[INFO] updating degradation parameter variance on i: 95
[INFO] updating degradation parameter values via random sampling on i: 95
[INFO] i: 95 mission_id: 1189 rul_hat: 15.79 flight_time: 13.47 distance: 994.86 R0: 0.01895 Q: 12.99 Req: 0.28807
[INFO] success on i: 95 mission_id: 1189
[INFO] forecasting degradation values: r_mu: 0.021901 q_mu: 11.898172 m_mu: 0.305983
```

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[INFO] digital twin degradation parameters: 0.0219 12.0865 0.3060
[INFO] DigitalTwin selecting trajectory: <13> with path_time: 13.94 that meets constraint: path_time < 15.79
[INFO] simulating digital twin on i 95, mission_id: 1189
[INFO] resampling for twin run # 2
[INFO] digital twin degradation parameters: 0.0221 11.7831 0.3095
[INFO] simulating digital twin on i 95, mission_id: 1189
[INFO] resampling for twin run # 3
[INFO] digital twin degradation parameters: 0.0220 11.8132 0.3132
[INFO] simulating digital twin on i 95, mission_id: 1189
[INFO] resampling for twin run # 4
[INFO] digital twin degradation parameters: 0.0219 11.5262 0.3036
[INFO] simulating digital twin on i 95, mission_id: 1189
[INFO] digital twin degradation parameters: 0.0219 11.5262 0.3036
[INFO] DigitalTwin mean parameter values: R0 = 0.02198  Q = 11.80  Req = 0.30809
  stop code counts: low_soc: 0 pos_err: 0  success: 4
[INFO] digital twin mission success on i: 95 mission_id: 1189
   trajectory <13> selected for TrueSystem
[INFO] simulating true system on i: 96
[INFO] updating degradation parameter variance on i: 96
[INFO] updating degradation parameter values via random sampling on i: 96
[INFO] i: 96 mission_id: 1190 rul_hat: 15.79 flight_time: 13.94 distance: 1047.88 R0: 0.01997 Q: 12.73 Req: 0.30318
[INFO] success on i: 96 mission_id: 1190
[INFO] forecasting degradation values: r_mu: 0.022946 q_mu: 12.499960 m_mu: 0.301600
[INFO] digital twin degradation parameters: 0.0230 12.1382 0.2940
[INFO] DigitalTwin selecting trajectory: <9> with path_time: 13.45 that meets constraint: path_time < 15.79
[INFO] simulating digital twin on i 96, mission_id: 1190
[INFO] resampling for twin run # 2
[INFO] digital twin degradation parameters: 0.0230 12.8865 0.3108
[INFO] simulating digital twin on i 96, mission_id: 1190
[INFO] resampling for twin run # 3
[INFO] digital twin degradation parameters: 0.0229 12.5104 0.3038
[INFO] simulating digital twin on i 96, mission_id: 1190
[INFO] resampling for twin run # 4
[INFO] digital twin degradation parameters: 0.0230 12.5507 0.3026
[INFO] simulating digital twin on i 96, mission_id: 1190
[INFO] digital twin degradation parameters: 0.0230 12.5507 0.3026
[INFO] DigitalTwin mean parameter values: R0 = 0.02296  Q = 12.52  Req = 0.30278
  stop code counts: low_soc: 0 pos_err: 0  success: 4
[INFO] digital twin mission success on i: 96 mission_id: 1190
   trajectory <9> selected for TrueSystem
[INFO] simulating true system on i: 97
[INFO] updating degradation parameter variance on i: 97
[INFO] updating degradation parameter values via random sampling on i: 97
[INFO] i: 97 mission_id: 1191 rul_hat: 15.79 flight_time: 13.47 distance: 994.75 R0: 0.02107 Q: 11.84 Req: 0.30050
[INFO] success on i: 97 mission_id: 1191
[INFO] forecasting degradation values: r_mu: 0.023942 q_mu: 12.315072 m_mu: 0.312023
[INFO] digital twin degradation parameters: 0.0239 12.1979 0.3127
[INFO] DigitalTwin selecting trajectory: <13> with path_time: 13.94 that meets constraint: path_time < 15.79
[INFO] simulating digital twin on i 97, mission_id: 1191
[INFO] resampling for twin run # 2
[INFO] digital twin degradation parameters: 0.0239 11.9026 0.3065
[INFO] simulating digital twin on i 97, mission_id: 1191
[INFO] resampling for twin run # 3
[INFO] digital twin degradation parameters: 0.0239 12.2725 0.3067
[INFO] simulating digital twin on i 97, mission_id: 1191
[INFO] resampling for twin run # 4
[INFO] digital twin degradation parameters: 0.0238 12.4683 0.3127
[INFO] simulating digital twin on i 97, mission_id: 1191
[INFO] digital twin degradation parameters: 0.0238 12.4683 0.3127
[INFO] DigitalTwin mean parameter values: R0 = 0.02390  Q = 12.21  Req = 0.30964
  stop code counts: low_soc: 0 pos_err: 0  success: 4
[INFO] digital twin mission success on i: 97 mission_id: 1191
   trajectory <13> selected for TrueSystem
[INFO] simulating true system on i: 98
[INFO] updating degradation parameter variance on i: 98
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[INFO] updating degradation parameter values via random sampling on i: 98
[INFO] i: 98 mission_id: 1192 rul_hat: 15.79 flight_time: 13.94 distance: 1047.77 R0: 0.02212 Q: 12.62 Req: 0.29563
[INFO] success on i: 98 mission_id: 1192
[INFO] forecasting degradation values: r_mu: 0.025330 q_mu: 12.117233 m_mu: 0.311160
[INFO] digital twin degradation parameters: 0.0251 12.1520 0.3100
[INFO] DigitalTwin selecting trajectory: <9> with path_time: 13.45 that meets constraint: path_time < 15.79
[INFO] simulating digital twin on i 98, mission_id: 1192
[INFO] resampling for twin run # 2
[INFO] digital twin degradation parameters: 0.0253 12.1544 0.3076
[INFO] simulating digital twin on i 98, mission_id: 1192
[INFO] resampling for twin run # 3
[INFO] digital twin degradation parameters: 0.0254 12.1302 0.3085
[INFO] simulating digital twin on i 98, mission_id: 1192
[INFO] resampling for twin run # 4
[INFO] digital twin degradation parameters: 0.0253 12.5718 0.3137
[INFO] simulating digital twin on i 98, mission_id: 1192
[INFO] digital twin degradation parameters: 0.0253 12.5718 0.3137
[INFO] DigitalTwin mean parameter values: R0 = 0.02529  Q = 12.25  Req = 0.30994
  stop code counts: low_soc: 0 pos_err: 0  success: 4
[INFO] digital twin mission success on i: 98 mission_id: 1192
   trajectory <9> selected for TrueSystem
[INFO] simulating true system on i: 99
[INFO] updating degradation parameter variance on i: 99
[INFO] updating degradation parameter values via random sampling on i: 99
[INFO] i: 99 mission_id: 1193 rul_hat: 15.79 flight_time: 13.47 distance: 994.78 R0: 0.02280 Q: 12.53 Req: 0.30465
[INFO] success on i: 99 mission_id: 1193
[INFO] forecasting degradation values: r_mu: 0.026543 q_mu: 12.470941 m_mu: 0.310446
[INFO] digital twin degradation parameters: 0.0266 12.4725 0.3190
[INFO] DigitalTwin selecting trajectory: <14> with path_time: 14.81 that meets constraint: path_time < 15.79
[INFO] simulating digital twin on i 99, mission_id: 1193
[INFO] resampling for twin run # 2
[INFO] digital twin degradation parameters: 0.0265 12.7667 0.3144
[INFO] simulating digital twin on i 99, mission_id: 1193
[INFO] resampling for twin run # 3
[INFO] digital twin degradation parameters: 0.0267 12.4174 0.3112
[INFO] simulating digital twin on i 99, mission_id: 1193
[INFO] resampling for twin run # 4
[INFO] digital twin degradation parameters: 0.0264 12.7073 0.3099
[INFO] simulating digital twin on i 99, mission_id: 1193
[INFO] digital twin degradation parameters: 0.0264 12.7073 0.3099
[INFO] DigitalTwin mean parameter values: R0 = 0.02653  Q = 12.59  Req = 0.31362
  stop code counts: low_soc: 0 pos_err: 0  success: 4
[INFO] digital twin mission success on i: 99 mission_id: 1193
   trajectory <14> selected for TrueSystem
[INFO] simulating true system on i: 100
Bumping sigmax
[INFO] updating degradation parameter variance on i: 100
[INFO] updating degradation parameter values via random sampling on i: 100
[INFO] i: 100 mission_id: 1194 rul_hat: 15.79 flight_time: 14.83 distance: 1083.97 R0: 0.02363 Q: 12.65 Req: 0.30195
[INFO] success on i: 100 mission_id: 1194
[INFO] forecasting degradation values: r_mu: 0.027568 q_mu: 12.461694 m_mu: 0.313385
[INFO] digital twin degradation parameters: 0.0276 12.2822 0.3107
[INFO] DigitalTwin selecting trajectory: <13> with path_time: 13.94 that meets constraint: path_time < 15.79
[INFO] simulating digital twin on i 100, mission_id: 1194
[INFO] resampling for twin run # 2
[INFO] digital twin degradation parameters: 0.0274 12.3272 0.3279
[INFO] simulating digital twin on i 100, mission_id: 1194
[INFO] resampling for twin run # 3
[INFO] digital twin degradation parameters: 0.0276 12.5155 0.3113
[INFO] simulating digital twin on i 100, mission_id: 1194
[INFO] resampling for twin run # 4
[INFO] digital twin degradation parameters: 0.0274 12.4956 0.2980
[INFO] simulating digital twin on i 100, mission_id: 1194
[INFO] digital twin degradation parameters: 0.0274 12.4956 0.2980
[INFO] DigitalTwin mean parameter values: R0 = 0.02751  Q = 12.41  Req = 0.31200
```

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  stop code counts: low_soc: 0 pos_err: 0  success: 4
[INFO] digital twin mission success on i: 100 mission_id: 1194
   trajectory <13> selected for TrueSystem
[INFO] simulating true system on i: 101
Bumping sigmax
[INFO] updating degradation parameter variance on i: 101
[INFO] updating degradation parameter values via random sampling on i: 101
[INFO] i: 101 mission_id: 1195 rul_hat: 15.79 flight_time: 13.94 distance: 1047.84 R0: 0.02469 Q: 11.99 Req: 0.30319
[INFO] success on i: 101 mission_id: 1195
[INFO] forecasting degradation values: r_mu: 0.028664 q_mu: 12.684958 m_mu: 0.310814
[INFO] digital twin degradation parameters: 0.0288 12.8139 0.3086
[INFO] DigitalTwin selecting trajectory: <14> with path_time: 14.81 that meets constraint: path_time < 15.79
[INFO] simulating digital twin on i 101, mission_id: 1195
[INFO] resampling for twin run # 2
[INFO] digital twin degradation parameters: 0.0285 12.7923 0.3079
[INFO] simulating digital twin on i 101, mission_id: 1195
[INFO] resampling for twin run # 3
[INFO] digital twin degradation parameters: 0.0288 12.6556 0.3032
[INFO] simulating digital twin on i 101, mission_id: 1195
[INFO] resampling for twin run # 4
[INFO] digital twin degradation parameters: 0.0287 12.8643 0.3083
[INFO] simulating digital twin on i 101, mission_id: 1195
[INFO] digital twin degradation parameters: 0.0287 12.8643 0.3083
[INFO] DigitalTwin mean parameter values: R0 = 0.02870  Q = 12.78  Req = 0.30701
  stop code counts: low_soc: 0 pos_err: 0  success: 4
[INFO] digital twin mission success on i: 101 mission_id: 1195
   trajectory <14> selected for TrueSystem
[INFO] simulating true system on i: 102
Bumping sigmax
[INFO] updating degradation parameter variance on i: 102
[INFO] updating degradation parameter values via random sampling on i: 102
[INFO] i: 102 mission_id: 1196 rul_hat: 15.79 flight_time: 14.83 distance: 1084.12 R0: 0.02545 Q: 12.39 Req: 0.30713
[INFO] success on i: 102 mission_id: 1196
[INFO] forecasting degradation values: r_mu: 0.029842 q_mu: 12.384781 m_mu: 0.310017
[INFO] digital twin degradation parameters: 0.0298 12.3529 0.3093
[INFO] DigitalTwin selecting trajectory: <14> with path_time: 14.81 that meets constraint: path_time < 15.79
[INFO] simulating digital twin on i 102, mission_id: 1196
[INFO] resampling for twin run # 2
[INFO] digital twin degradation parameters: 0.0298 12.0872 0.3107
[INFO] simulating digital twin on i 102, mission_id: 1196
[INFO] resampling for twin run # 3
[INFO] digital twin degradation parameters: 0.0297 12.7255 0.3141
[INFO] simulating digital twin on i 102, mission_id: 1196
[INFO] resampling for twin run # 4
[INFO] digital twin degradation parameters: 0.0298 12.9009 0.3157
[INFO] simulating digital twin on i 102, mission_id: 1196
[INFO] digital twin degradation parameters: 0.0298 12.9009 0.3157
[INFO] DigitalTwin mean parameter values: R0 = 0.02979  Q = 12.52  Req = 0.31246
  stop code counts: low_soc: 0 pos_err: 0  success: 4
[INFO] digital twin mission success on i: 102 mission_id: 1196
   trajectory <14> selected for TrueSystem
[INFO] simulating true system on i: 103
Bumping sigmax
[INFO] updating degradation parameter variance on i: 103
[INFO] updating degradation parameter values via random sampling on i: 103
[INFO] i: 103 mission_id: 1197 rul_hat: 15.79 flight_time: 14.83 distance: 1083.99 R0: 0.02673 Q: 11.75 Req: 0.29984
[INFO] success on i: 103 mission_id: 1197
[INFO] forecasting degradation values: r_mu: 0.030870 q_mu: 12.176778 m_mu: 0.313194
[INFO] digital twin degradation parameters: 0.0308 12.0949 0.3066
[INFO] DigitalTwin selecting trajectory: <14> with path_time: 14.81 that meets constraint: path_time < 15.79
[INFO] simulating digital twin on i 103, mission_id: 1197
[INFO] resampling for twin run # 2
[INFO] digital twin degradation parameters: 0.0309 12.0396 0.3128
[INFO] simulating digital twin on i 103, mission_id: 1197
[INFO] resampling for twin run # 3
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[INFO] digital twin degradation parameters: 0.0310 11.7192 0.3084
[INFO] simulating digital twin on i 103, mission_id: 1197
[INFO] resampling for twin run # 4
[INFO] digital twin degradation parameters: 0.0308 12.3155 0.3081
[INFO] simulating digital twin on i 103, mission_id: 1197
[INFO] digital twin degradation parameters: 0.0308 12.3155 0.3081
[INFO] DigitalTwin mean parameter values: R0 = 0.03087  Q = 12.04  Req = 0.30896
  stop code counts: low_soc: 0 pos_err: 0  success: 4
[INFO] digital twin mission success on i: 103 mission_id: 1197
   trajectory <14> selected for TrueSystem
[INFO] simulating true system on i: 104
Bumping sigmax
[INFO] updating degradation parameter variance on i: 104
[INFO] updating degradation parameter values via random sampling on i: 104
[INFO] i: 104 mission_id: 1198 rul_hat: 15.79 flight_time: 14.83 distance: 1083.80 R0: 0.02760 Q: 12.39 Req: 0.30099
[INFO] success on i: 104 mission_id: 1198
[INFO] forecasting degradation values: r_mu: 0.032108 q_mu: 11.699849 m_mu: 0.307302
[INFO] digital twin degradation parameters: 0.0322 11.7854 0.3102
[INFO] DigitalTwin selecting trajectory: <14> with path_time: 14.81 that meets constraint: path_time < 15.79
[INFO] simulating digital twin on i 104, mission_id: 1198
[INFO] resampling for twin run # 2
[INFO] digital twin degradation parameters: 0.0319 11.7382 0.3109
[INFO] simulating digital twin on i 104, mission_id: 1198
[INFO] resampling for twin run # 3
[INFO] digital twin degradation parameters: 0.0322 11.6783 0.3155
[INFO] simulating digital twin on i 104, mission_id: 1198
[INFO] resampling for twin run # 4
[INFO] digital twin degradation parameters: 0.0321 11.5991 0.3078
[INFO] simulating digital twin on i 104, mission_id: 1198
[INFO] digital twin degradation parameters: 0.0321 11.5991 0.3078
[INFO] DigitalTwin mean parameter values: R0 = 0.03212  Q = 11.70  Req = 0.31110
  stop code counts: low_soc: 0 pos_err: 0  success: 4
[INFO] digital twin mission success on i: 104 mission_id: 1198
   trajectory <14> selected for TrueSystem
[INFO] simulating true system on i: 105
Bumping sigmax
[INFO] updating degradation parameter variance on i: 105
[INFO] updating degradation parameter values via random sampling on i: 105
[INFO] i: 105 mission_id: 1199 rul_hat: 15.79 flight_time: 14.83 distance: 1084.11 R0: 0.02858 Q: 12.34 Req: 0.31589
[INFO] success on i: 105 mission_id: 1199
[INFO] forecasting degradation values: r_mu: 0.033159 q_mu: 11.888060 m_mu: 0.302778
[INFO] digital twin degradation parameters: 0.0333 11.9501 0.2960
[INFO] DigitalTwin selecting trajectory: <9> with path_time: 13.45 that meets constraint: path_time < 15.79
[INFO] simulating digital twin on i 105, mission_id: 1199
[INFO] resampling for twin run # 2
[INFO] digital twin degradation parameters: 0.0332 12.2337 0.3061
[INFO] simulating digital twin on i 105, mission_id: 1199
[INFO] resampling for twin run # 3
[INFO] digital twin degradation parameters: 0.0330 12.0463 0.3061
[INFO] simulating digital twin on i 105, mission_id: 1199
[INFO] resampling for twin run # 4
[INFO] digital twin degradation parameters: 0.0333 11.9094 0.3041
[INFO] simulating digital twin on i 105, mission_id: 1199
[INFO] digital twin degradation parameters: 0.0333 11.9094 0.3041
[INFO] DigitalTwin mean parameter values: R0 = 0.03319  Q = 12.03  Req = 0.30307
  stop code counts: low_soc: 0 pos_err: 0  success: 4
[INFO] digital twin mission success on i: 105 mission_id: 1199
   trajectory <9> selected for TrueSystem
[INFO] simulating true system on i: 106
Bumping sigmax
[INFO] updating degradation parameter variance on i: 106
[INFO] updating degradation parameter values via random sampling on i: 106
[INFO] i: 106 mission_id: 1200 rul_hat: 15.79 flight_time: 13.47 distance: 994.81 R0: 0.02955 Q: 12.01 Req: 0.30162
[INFO] success on i: 106 mission_id: 1200
[INFO] forecasting degradation values: r_mu: 0.034113 q_mu: 11.930305 m_mu: 0.314439
```

```
[INFO] digital twin degradation parameters: 0.0341 11.7354 0.3080
[INFO] DigitalTwin selecting trajectory: <14> with path_time: 14.81 that meets constraint: path_time < 15.79
[INFO] simulating digital twin on i 106, mission_id: 1200
[INFO] resampling for twin run # 2
[INFO] digital twin degradation parameters: 0.0342 12.4872 0.3152
[INFO] simulating digital twin on i 106, mission_id: 1200
[INFO] resampling for twin run # 3
[INFO] digital twin degradation parameters: 0.0341 11.4407 0.3219
[INFO] simulating digital twin on i 106, mission_id: 1200
[INFO] resampling for twin run # 4
[INFO] digital twin degradation parameters: 0.0341 12.0280 0.3134
[INFO] simulating digital twin on i 106, mission_id: 1200
[INFO] digital twin degradation parameters: 0.0341 12.0280 0.3134
[INFO] DigitalTwin mean parameter values: R0 = 0.03413  Q = 11.92  Req = 0.31464
  stop code counts: low_soc: 0 pos_err: 0  success: 4
[INFO] digital twin mission success on i: 106 mission_id: 1200
   trajectory <14> selected for TrueSystem
[INFO] simulating true system on i: 107
Bumping sigmax
[INFO] updating degradation parameter variance on i: 107
[INFO] updating degradation parameter values via random sampling on i: 107
[INFO] i: 107 mission_id: 1201 rul_hat: 15.79 flight_time: 14.83 distance: 1083.80 R0: 0.03084 Q: 12.05 Req: 0.31073
[INFO] success on i: 107 mission_id: 1201
[INFO] forecasting degradation values: r_mu: 0.035294 q_mu: 11.661665 m_mu: 0.311326
[INFO] digital twin degradation parameters: 0.0352 11.6948 0.3039
[INFO] DigitalTwin selecting trajectory: <10> with path_time: 13.57 that meets constraint: path_time < 15.79
[INFO] simulating digital twin on i 107, mission_id: 1201
[INFO] resampling for twin run # 2
[INFO] digital twin degradation parameters: 0.0353 11.7431 0.3158
[INFO] simulating digital twin on i 107, mission_id: 1201
[INFO] resampling for twin run # 3
[INFO] digital twin degradation parameters: 0.0351 11.2978 0.3082
[INFO] simulating digital twin on i 107, mission_id: 1201
[INFO] resampling for twin run # 4
[INFO] digital twin degradation parameters: 0.0353 11.7481 0.3095
[INFO] simulating digital twin on i 107, mission_id: 1201
[INFO] digital twin degradation parameters: 0.0353 11.7481 0.3095
[INFO] DigitalTwin mean parameter values: R0 = 0.03523  Q = 11.62  Req = 0.30935
  stop code counts: low_soc: 0 pos_err: 0  success: 4
[INFO] digital twin mission success on i: 107 mission_id: 1201
   trajectory <10> selected for TrueSystem
[INFO] simulating true system on i: 108
Bumping sigmax
[INFO] updating degradation parameter variance on i: 108
[INFO] updating degradation parameter values via random sampling on i: 108
[INFO] i: 108 mission_id: 1202 rul_hat: 15.79 flight_time: 13.28 distance: 979.92 R0: 0.03194 Q: 12.54 Req: 0.30568
[WARN] true system position error threshold exceeded on i: 108 mission_id: 1202
[INFO] forecasting degradation values: r_mu: 0.036354 q_mu: 11.769819 m_mu: 0.309798
[INFO] digital twin degradation parameters: 0.0363 11.3123 0.3105
[INFO] DigitalTwin selecting trajectory: <15> with path_time: 17.63 to explore constraint boundary < 15.79
[INFO] simulating digital twin on i 108, mission_id: 1202
[INFO] resampling for twin run # 2
[INFO] digital twin degradation parameters: 0.0365 11.7119 0.3110
[INFO] simulating digital twin on i 108, mission_id: 1202
[INFO] resampling for twin run # 3
[INFO] digital twin degradation parameters: 0.0365 11.9168 0.3114
[INFO] simulating digital twin on i 108, mission_id: 1202
[INFO] resampling for twin run # 4
[INFO] digital twin degradation parameters: 0.0365 11.5413 0.3075
[INFO] simulating digital twin on i 108, mission_id: 1202
[INFO] digital twin degradation parameters: 0.0365 11.5413 0.3075
[INFO] DigitalTwin mean parameter values: R0 = 0.03642  Q = 11.62  Req = 0.31008
  stop code counts: low_soc: 4 pos_err: 0  success: 0
[WARN] DigitalTwin low soc threshold exceeded on i: 108 mission_id: 1202
[INFO] updating RUL from 15.79 to 14.55
```

```
[INFO] selecting new trajectory to repeat DigitalTwin simulation
[INFO] DigitalTwin selecting trajectory: <10> with path_time: 13.57 that meets constraint: path_time < 14.55
[INFO] simulating digital twin on i 108, mission_id: 1202
[INFO] resampling for twin run # 2
[INFO] digital twin degradation parameters: 0.0363 11.9499 0.3073
[INFO] simulating digital twin on i 108, mission_id: 1202
[INFO] resampling for twin run # 3
[INFO] digital twin degradation parameters: 0.0364 11.7240 0.3076
[INFO] simulating digital twin on i 108, mission_id: 1202
[INFO] resampling for twin run # 4
[INFO] digital twin degradation parameters: 0.0364 11.8426 0.2999
[INFO] simulating digital twin on i 108, mission_id: 1202
[INFO] digital twin degradation parameters: 0.0364 11.8426 0.2999
[INFO] DigitalTwin mean parameter values: R0 = 0.03640  Q = 11.76  Req = 0.30557
  stop code counts: low_soc: 0 pos_err: 0  success: 4
[INFO] digital twin mission success on i: 108 mission_id: 1202
   trajectory <10> selected for TrueSystem
[INFO] simulating true system on i: 109
Bumping sigmax
[INFO] updating degradation parameter variance on i: 109
[INFO] updating degradation parameter values via random sampling on i: 109
[INFO] i: 109 mission_id: 1203 rul_hat: 14.55 flight_time: 13.30 distance: 982.80 R0: 0.03310 Q: 11.70 Req: 0.31264
[WARN] true system position error threshold exceeded on i: 109 mission_id: 1203
[INFO] forecasting degradation values: r_mu: 0.037540 q_mu: 12.237734 m_mu: 0.312493
[INFO] digital twin degradation parameters: 0.0375 12.2342 0.3188
[INFO] DigitalTwin selecting trajectory: <14> with path_time: 14.81 to explore constraint boundary < 14.55
[INFO] simulating digital twin on i 109, mission_id: 1203
[INFO] resampling for twin run # 2
[INFO] digital twin degradation parameters: 0.0374 12.6045 0.3179
[INFO] simulating digital twin on i 109, mission_id: 1203
[INFO] resampling for twin run # 3
[INFO] digital twin degradation parameters: 0.0376 12.8454 0.3102
[INFO] simulating digital twin on i 109, mission_id: 1203
[INFO] resampling for twin run # 4
[INFO] digital twin degradation parameters: 0.0377 11.9611 0.3105
[INFO] simulating digital twin on i 109, mission_id: 1203
[INFO] digital twin degradation parameters: 0.0377 11.9611 0.3105
[INFO] DigitalTwin mean parameter values: R0 = 0.03753  Q = 12.41  Req = 0.31433
  stop code counts: low_soc: 0 pos_err: 0  success: 4
[INFO] digital twin mission success on i: 109 mission_id: 1203
   trajectory <14> selected for TrueSystem
[INFO] TrueSystem selecting trajectory: <9> with path_time: 13.45 that meets constraint: path_time < 14.55
[INFO] simulating true system on i: 110
Bumping sigmax
[INFO] updating degradation parameter variance on i: 110
[INFO] updating degradation parameter values via random sampling on i: 110
[INFO] i: 110 mission_id: 1204 rul_hat: 14.55 flight_time: 13.47 distance: 994.76 R0: 0.03442 Q: 11.70 Req: 0.30606
[INFO] success on i: 110 mission_id: 1204
[INFO] forecasting degradation values: r_mu: 0.038837 q_mu: 11.634375 m_mu: 0.316172
[INFO] digital twin degradation parameters: 0.0386 11.3960 0.3090
[INFO] DigitalTwin selecting trajectory: <8> with path_time: 13.31 that meets constraint: path_time < 14.55
[INFO] simulating digital twin on i 110, mission_id: 1204
[INFO] resampling for twin run # 2
[INFO] digital twin degradation parameters: 0.0389 11.9037 0.3062
[INFO] simulating digital twin on i 110, mission_id: 1204
[INFO] resampling for twin run # 3
[INFO] digital twin degradation parameters: 0.0387 11.5146 0.3209
[INFO] simulating digital twin on i 110, mission_id: 1204
[INFO] resampling for twin run # 4
[INFO] digital twin degradation parameters: 0.0390 12.0020 0.3142
[INFO] simulating digital twin on i 110, mission_id: 1204
[INFO] digital twin degradation parameters: 0.0390 12.0020 0.3142
[INFO] DigitalTwin mean parameter values: R0 = 0.03877  Q = 11.70  Req = 0.31256
  stop code counts: low_soc: 0 pos_err: 0  success: 4
[INFO] digital twin mission success on i: 110 mission_id: 1204
```

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   trajectory <8> selected for TrueSystem
[INFO] simulating true system on i: 111
Bumping sigmax
[INFO] updating degradation parameter variance on i: 111
[INFO] updating degradation parameter values via random sampling on i: 111
[INFO] i: 111 mission_id: 1205 rul_hat: 14.55 flight_time: 13.27 distance: 989.97 R0: 0.03557 Q: 11.56 Req: 0.31687
[INFO] success on i: 111 mission_id: 1205
[INFO] forecasting degradation values: r_mu: 0.040360 q_mu: 11.517833 m_mu: 0.312096
[INFO] digital twin degradation parameters: 0.0404 11.1353 0.3114
[INFO] DigitalTwin selecting trajectory: <9> with path_time: 13.45 that meets constraint: path_time < 14.55
[INFO] simulating digital twin on i 111, mission_id: 1205
[INFO] resampling for twin run # 2
[INFO] digital twin degradation parameters: 0.0405 11.8177 0.3145
[INFO] simulating digital twin on i 111, mission_id: 1205
[INFO] resampling for twin run # 3
[INFO] digital twin degradation parameters: 0.0403 11.3984 0.3062
[INFO] simulating digital twin on i 111, mission_id: 1205
[INFO] resampling for twin run # 4
[INFO] digital twin degradation parameters: 0.0405 11.2932 0.3024
[INFO] simulating digital twin on i 111, mission_id: 1205
[INFO] digital twin degradation parameters: 0.0405 11.2932 0.3024
[INFO] DigitalTwin mean parameter values: R0 = 0.04043  Q = 11.41  Req = 0.30863
  stop code counts: low_soc: 0 pos_err: 0  success: 4
[INFO] digital twin mission success on i: 111 mission_id: 1205
   trajectory <9> selected for TrueSystem
[INFO] simulating true system on i: 112
Bumping sigmax
[INFO] updating degradation parameter variance on i: 112
[INFO] updating degradation parameter values via random sampling on i: 112
[INFO] i: 112 mission_id: 1206 rul_hat: 14.55 flight_time: 13.47 distance: 994.76 R0: 0.03692 Q: 12.13 Req: 0.31641
[INFO] success on i: 112 mission_id: 1206
[INFO] forecasting degradation values: r_mu: 0.041767 q_mu: 11.331355 m_mu: 0.318318
[INFO] digital twin degradation parameters: 0.0417 11.3824 0.3203
[INFO] DigitalTwin selecting trajectory: <10> with path_time: 13.57 that meets constraint: path_time < 14.55
[INFO] simulating digital twin on i 112, mission_id: 1206
[INFO] resampling for twin run # 2
[INFO] digital twin degradation parameters: 0.0420 11.5959 0.3059
[INFO] simulating digital twin on i 112, mission_id: 1206
[INFO] resampling for twin run # 3
[INFO] digital twin degradation parameters: 0.0417 11.3232 0.3208
[INFO] simulating digital twin on i 112, mission_id: 1206
[INFO] resampling for twin run # 4
[INFO] digital twin degradation parameters: 0.0417 11.3199 0.3167
[INFO] simulating digital twin on i 112, mission_id: 1206
[INFO] digital twin degradation parameters: 0.0417 11.3199 0.3167
[INFO] DigitalTwin mean parameter values: R0 = 0.04178  Q = 11.41  Req = 0.31592
  stop code counts: low_soc: 0 pos_err: 0  success: 4
[INFO] digital twin mission success on i: 112 mission_id: 1206
   trajectory <10> selected for TrueSystem
[INFO] simulating true system on i: 113
Bumping sigmax
[INFO] updating degradation parameter variance on i: 113
[INFO] updating degradation parameter values via random sampling on i: 113
[INFO] i: 113 mission_id: 1207 rul_hat: 14.55 flight_time: 13.27 distance: 977.11 R0: 0.03821 Q: 12.24 Req: 0.31521
[WARN] true system position error threshold exceeded on i: 113 mission_id: 1207
[INFO] forecasting degradation values: r_mu: 0.043222 q_mu: 11.692016 m_mu: 0.320970
[INFO] digital twin degradation parameters: 0.0435 11.4695 0.3197
[INFO] DigitalTwin selecting trajectory: <10> with path_time: 13.57 that meets constraint: path_time < 14.55
[INFO] simulating digital twin on i 113, mission_id: 1207
[INFO] resampling for twin run # 2
[INFO] digital twin degradation parameters: 0.0433 11.8810 0.3166
[INFO] simulating digital twin on i 113, mission_id: 1207
[INFO] resampling for twin run # 3
[INFO] digital twin degradation parameters: 0.0432 11.5819 0.3251
[INFO] simulating digital twin on i 113, mission_id: 1207
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[INFO] resampling for twin run # 4
[INFO] digital twin degradation parameters: 0.0431 12.0810 0.3132
[INFO] simulating digital twin on i 113, mission_id: 1207
[INFO] digital twin degradation parameters: 0.0431 12.0810 0.3132
[INFO] DigitalTwin mean parameter values: R0 = 0.04329  Q = 11.75  Req = 0.31865
  stop code counts: low_soc: 0 pos_err: 0  success: 4
[INFO] digital twin mission success on i: 113 mission_id: 1207
   trajectory <10> selected for TrueSystem
[INFO] simulating true system on i: 114
Bumping sigmax
[INFO] updating degradation parameter variance on i: 114
[INFO] updating degradation parameter values via random sampling on i: 114
[INFO] i: 114 mission_id: 1208 rul_hat: 14.55 flight_time: 13.27 distance: 977.22 R0: 0.03932 Q: 11.28 Req: 0.31361
[WARN] true system position error threshold exceeded on i: 114 mission_id: 1208
[INFO] forecasting degradation values: r_mu: 0.044831 q_mu: 11.542246 m_mu: 0.322202
[INFO] digital twin degradation parameters: 0.0447 11.9295 0.3214
[INFO] DigitalTwin selecting trajectory: <13> with path_time: 13.94 that meets constraint: path_time < 14.55
[INFO] simulating digital twin on i 114, mission_id: 1208
[INFO] resampling for twin run # 2
[INFO] digital twin degradation parameters: 0.0447 11.6291 0.3217
[INFO] simulating digital twin on i 114, mission_id: 1208
[INFO] resampling for twin run # 3
[INFO] digital twin degradation parameters: 0.0449 11.8315 0.3176
[INFO] simulating digital twin on i 114, mission_id: 1208
[INFO] resampling for twin run # 4
[INFO] digital twin degradation parameters: 0.0447 11.6563 0.3216
[INFO] simulating digital twin on i 114, mission_id: 1208
[INFO] digital twin degradation parameters: 0.0447 11.6563 0.3216
[INFO] DigitalTwin mean parameter values: R0 = 0.04477  Q = 11.76  Req = 0.32057
  stop code counts: low_soc: 0 pos_err: 0  success: 4
[INFO] digital twin mission success on i: 114 mission_id: 1208
   trajectory <13> selected for TrueSystem
[INFO] simulating true system on i: 115
Bumping sigmax
[INFO] updating degradation parameter variance on i: 115
[INFO] updating degradation parameter values via random sampling on i: 115
[INFO] i: 115 mission_id: 1209 rul_hat: 14.55 flight_time: 13.93 distance: 1047.78 R0: 0.04070 Q: 11.38 Req: 0.31355
[INFO] success on i: 115 mission_id: 1209
[INFO] forecasting degradation values: r_mu: 0.046161 q_mu: 11.445654 m_mu: 0.324353
[INFO] digital twin degradation parameters: 0.0462 11.8357 0.3226
[INFO] DigitalTwin selecting trajectory: <14> with path_time: 14.81 to explore constraint boundary < 14.55
[INFO] simulating digital twin on i 115, mission_id: 1209
[INFO] resampling for twin run # 2
[INFO] digital twin degradation parameters: 0.0463 11.8248 0.3261
[INFO] simulating digital twin on i 115, mission_id: 1209
[INFO] resampling for twin run # 3
[INFO] digital twin degradation parameters: 0.0460 11.2397 0.3236
[INFO] simulating digital twin on i 115, mission_id: 1209
[INFO] resampling for twin run # 4
[INFO] digital twin degradation parameters: 0.0460 11.3146 0.3307
[INFO] simulating digital twin on i 115, mission_id: 1209
[INFO] digital twin degradation parameters: 0.0460 11.3146 0.3307
[INFO] DigitalTwin mean parameter values: R0 = 0.04612  Q = 11.55  Req = 0.32577
  stop code counts: low_soc: 0 pos_err: 0  success: 4
[INFO] digital twin mission success on i: 115 mission_id: 1209
   trajectory <14> selected for TrueSystem
[INFO] TrueSystem selecting trajectory: <9> with path_time: 13.45 that meets constraint: path_time < 14.55
[INFO] simulating true system on i: 116
Bumping sigmax
[INFO] updating degradation parameter variance on i: 116
[INFO] updating degradation parameter values via random sampling on i: 116
[INFO] i: 116 mission_id: 1210 rul_hat: 14.55 flight_time: 13.47 distance: 994.81 R0: 0.04230 Q: 12.01 Req: 0.31810
[INFO] success on i: 116 mission_id: 1210
[INFO] forecasting degradation values: r_mu: 0.047720 q_mu: 11.093550 m_mu: 0.322535
[INFO] digital twin degradation parameters: 0.0478 10.7857 0.3181
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[INFO] DigitalTwin selecting trajectory: <9> with path_time: 13.45 that meets constraint: path_time < 14.55
[INFO] simulating digital twin on i 116, mission_id: 1210
[INFO] resampling for twin run # 2
[INFO] digital twin degradation parameters: 0.0477 11.1622 0.3192
[INFO] simulating digital twin on i 116, mission_id: 1210
[INFO] resampling for twin run # 3
[INFO] digital twin degradation parameters: 0.0478 10.9180 0.3238
[INFO] simulating digital twin on i 116, mission_id: 1210
[INFO] resampling for twin run # 4
[INFO] digital twin degradation parameters: 0.0478 11.4518 0.3170
[INFO] simulating digital twin on i 116, mission_id: 1210
[INFO] digital twin degradation parameters: 0.0478 11.4518 0.3170
[INFO] DigitalTwin mean parameter values: R0 = 0.04775  Q = 11.08  Req = 0.31952
  stop code counts: low_soc: 0 pos_err: 0  success: 4
[INFO] digital twin mission success on i: 116 mission_id: 1210
   trajectory <9> selected for TrueSystem
[INFO] simulating true system on i: 117
Bumping sigmax
[INFO] updating degradation parameter variance on i: 117
[INFO] updating degradation parameter values via random sampling on i: 117
[INFO] i: 117 mission_id: 1211 rul_hat: 14.55 flight_time: 13.47 distance: 994.83 R0: 0.04334 Q: 11.06 Req: 0.32107
[INFO] success on i: 117 mission_id: 1211
[INFO] forecasting degradation values: r_mu: 0.049393 q_mu: 11.348491 m_mu: 0.320201
[INFO] digital twin degradation parameters: 0.0495 11.0817 0.3192
[INFO] DigitalTwin selecting trajectory: <8> with path_time: 13.31 that meets constraint: path_time < 14.55
[INFO] simulating digital twin on i 117, mission_id: 1211
[INFO] resampling for twin run # 2
[INFO] digital twin degradation parameters: 0.0494 11.7199 0.3194
[INFO] simulating digital twin on i 117, mission_id: 1211
[INFO] resampling for twin run # 3
[INFO] digital twin degradation parameters: 0.0493 11.3225 0.3115
[INFO] simulating digital twin on i 117, mission_id: 1211
[INFO] resampling for twin run # 4
[INFO] digital twin degradation parameters: 0.0493 11.1932 0.3271
[INFO] simulating digital twin on i 117, mission_id: 1211
[INFO] digital twin degradation parameters: 0.0493 11.1932 0.3271
[INFO] DigitalTwin mean parameter values: R0 = 0.04937  Q = 11.33  Req = 0.31929
  stop code counts: low_soc: 0 pos_err: 0  success: 4
[INFO] digital twin mission success on i: 117 mission_id: 1211
   trajectory <8> selected for TrueSystem
[INFO] simulating true system on i: 118
Bumping sigmax
[INFO] updating degradation parameter variance on i: 118
[INFO] updating degradation parameter values via random sampling on i: 118
[INFO] i: 118 mission_id: 1212 rul_hat: 14.55 flight_time: 13.27 distance: 990.13 R0: 0.04497 Q: 11.94 Req: 0.32374
[INFO] success on i: 118 mission_id: 1212
[INFO] forecasting degradation values: r_mu: 0.050715 q_mu: 10.981412 m_mu: 0.329851
[INFO] digital twin degradation parameters: 0.0508 10.9255 0.3254
[INFO] DigitalTwin selecting trajectory: <13> with path_time: 13.94 that meets constraint: path_time < 14.55
[INFO] simulating digital twin on i 118, mission_id: 1212
[INFO] resampling for twin run # 2
[INFO] digital twin degradation parameters: 0.0506 11.1101 0.3290
[INFO] simulating digital twin on i 118, mission_id: 1212
[INFO] resampling for twin run # 3
[INFO] digital twin degradation parameters: 0.0507 10.8513 0.3333
[INFO] simulating digital twin on i 118, mission_id: 1212
[INFO] resampling for twin run # 4
[INFO] digital twin degradation parameters: 0.0507 11.0704 0.3332
[INFO] simulating digital twin on i 118, mission_id: 1212
[INFO] digital twin degradation parameters: 0.0507 11.0704 0.3332
[INFO] DigitalTwin mean parameter values: R0 = 0.05068  Q = 10.99  Req = 0.33022
  stop code counts: low_soc: 0 pos_err: 0  success: 4
[INFO] digital twin mission success on i: 118 mission_id: 1212
   trajectory <13> selected for TrueSystem
[INFO] simulating true system on i: 119
```

```
Bumping sigmax
[INFO] updating degradation parameter variance on i: 119
[INFO] updating degradation parameter values via random sampling on i: 119
[INFO] i: 119 mission_id: 1213 rul_hat: 14.55 flight_time: 13.93 distance: 1047.89 R0: 0.04661 Q: 11.15 Req: 0.32380
[INFO] success on i: 119 mission_id: 1213
[INFO] forecasting degradation values: r_mu: 0.052417 q_mu: 11.308938 m_mu: 0.326312
[INFO] digital twin degradation parameters: 0.0525 10.7644 0.3269
[INFO] DigitalTwin selecting trajectory: <9> with path_time: 13.45 that meets constraint: path_time < 14.55
[INFO] simulating digital twin on i 119, mission_id: 1213
[INFO] resampling for twin run # 2
[INFO] digital twin degradation parameters: 0.0524 11.3935 0.3235
[INFO] simulating digital twin on i 119, mission_id: 1213
[INFO] resampling for twin run # 3
[INFO] digital twin degradation parameters: 0.0524 11.5960 0.3259
[INFO] simulating digital twin on i 119, mission_id: 1213
[INFO] resampling for twin run # 4
[INFO] digital twin degradation parameters: 0.0523 11.2831 0.3285
[INFO] simulating digital twin on i 119, mission_id: 1213
[INFO] digital twin degradation parameters: 0.0523 11.2831 0.3285
[INFO] DigitalTwin mean parameter values: R0 = 0.05241  Q = 11.26  Req = 0.32619
  stop code counts: low_soc: 0 pos_err: 0  success: 4
[INFO] digital twin mission success on i: 119 mission_id: 1213
   trajectory <9> selected for TrueSystem
[INFO] simulating true system on i: 120
Bumping sigmax
[INFO] updating degradation parameter variance on i: 120
[INFO] updating degradation parameter values via random sampling on i: 120
[INFO] i: 120 mission_id: 1214 rul_hat: 14.55 flight_time: 13.47 distance: 994.81 R0: 0.04775 Q: 11.73 Req: 0.32151
[INFO] success on i: 120 mission_id: 1214
[INFO] forecasting degradation values: r_mu: 0.054153 q_mu: 10.921257 m_mu: 0.330310
[INFO] digital twin degradation parameters: 0.0541 11.3287 0.3318
[INFO] DigitalTwin selecting trajectory: <8> with path_time: 13.31 that meets constraint: path_time < 14.55
[INFO] simulating digital twin on i 120, mission_id: 1214
[INFO] resampling for twin run # 2
[INFO] digital twin degradation parameters: 0.0541 10.8748 0.3347
[INFO] simulating digital twin on i 120, mission_id: 1214
[INFO] resampling for twin run # 3
[INFO] digital twin degradation parameters: 0.0541 10.9810 0.3245
[INFO] simulating digital twin on i 120, mission_id: 1214
[INFO] resampling for twin run # 4
[INFO] digital twin degradation parameters: 0.0542 11.4802 0.3295
[INFO] simulating digital twin on i 120, mission_id: 1214
[INFO] digital twin degradation parameters: 0.0542 11.4802 0.3295
[INFO] DigitalTwin mean parameter values: R0 = 0.05412  Q = 11.17  Req = 0.33011
  stop code counts: low_soc: 0 pos_err: 0  success: 4
[INFO] digital twin mission success on i: 120 mission_id: 1214
   trajectory <8> selected for TrueSystem
[INFO] simulating true system on i: 121
Bumping sigmax
[INFO] updating degradation parameter variance on i: 121
[INFO] updating degradation parameter values via random sampling on i: 121
[INFO] i: 121 mission_id: 1215 rul_hat: 14.55 flight_time: 13.28 distance: 990.14 R0: 0.04953 Q: 11.67 Req: 0.32013
[INFO] success on i: 121 mission_id: 1215
[INFO] forecasting degradation values: r_mu: 0.055598 q_mu: 11.356060 m_mu: 0.327716
[INFO] digital twin degradation parameters: 0.0556 11.3479 0.3308
[INFO] DigitalTwin selecting trajectory: <13> with path_time: 13.94 that meets constraint: path_time < 14.55
[INFO] simulating digital twin on i 121, mission_id: 1215
[INFO] resampling for twin run # 2
[INFO] digital twin degradation parameters: 0.0556 11.3088 0.3193
[INFO] simulating digital twin on i 121, mission_id: 1215
[INFO] resampling for twin run # 3
[INFO] digital twin degradation parameters: 0.0554 10.9230 0.3278
[INFO] simulating digital twin on i 121, mission_id: 1215
[INFO] resampling for twin run # 4
[INFO] digital twin degradation parameters: 0.0556 11.5228 0.3224
```

```
[INFO] simulating digital twin on i 121, mission_id: 1215
[INFO] digital twin degradation parameters: 0.0556 11.5228 0.3224
[INFO] DigitalTwin mean parameter values: R0 = 0.05556  Q = 11.28  Req = 0.32508
  stop code counts: low_soc: 0 pos_err: 0  success: 4
[INFO] digital twin mission success on i: 121 mission_id: 1215
   trajectory <13> selected for TrueSystem
[INFO] simulating true system on i: 122
Bumping sigmax
[INFO] updating degradation parameter variance on i: 122
[INFO] updating degradation parameter values via random sampling on i: 122
[INFO] i: 122 mission_id: 1216 rul_hat: 14.55 flight_time: 13.93 distance: 1047.70 R0: 0.05123 Q: 11.29 Req: 0.32552
[INFO] success on i: 122 mission_id: 1216
[INFO] forecasting degradation values: r_mu: 0.057436 q_mu: 11.409888 m_mu: 0.325960
[INFO] digital twin degradation parameters: 0.0574 11.3084 0.3244
[INFO] DigitalTwin selecting trajectory: <11> with path_time: 16.38 to explore constraint boundary < 14.55
[INFO] simulating digital twin on i 122, mission_id: 1216
[INFO] resampling for twin run # 2
[INFO] digital twin degradation parameters: 0.0575 10.8671 0.3185
[INFO] simulating digital twin on i 122, mission_id: 1216
[INFO] resampling for twin run # 3
[INFO] digital twin degradation parameters: 0.0574 11.4466 0.3278
[INFO] simulating digital twin on i 122, mission_id: 1216
[INFO] resampling for twin run # 4
[INFO] digital twin degradation parameters: 0.0577 10.9706 0.3173
[INFO] simulating digital twin on i 122, mission_id: 1216
[INFO] digital twin degradation parameters: 0.0577 10.9706 0.3173
[INFO] DigitalTwin mean parameter values: R0 = 0.05749  Q = 11.15  Req = 0.32200
  stop code counts: low_soc: 4 pos_err: 0  success: 0
[WARN] DigitalTwin low soc threshold exceeded on i: 122 mission_id: 1216
[INFO] updating RUL from 14.55 to 13.99
[INFO] selecting new trajectory to repeat DigitalTwin simulation
[INFO] DigitalTwin selecting trajectory: <10> with path_time: 13.57 that meets constraint: path_time < 13.99
[INFO] simulating digital twin on i 122, mission_id: 1216
[INFO] resampling for twin run # 2
[INFO] digital twin degradation parameters: 0.0573 11.6481 0.3238
[INFO] simulating digital twin on i 122, mission_id: 1216
[INFO] resampling for twin run # 3
[INFO] digital twin degradation parameters: 0.0575 11.4607 0.3180
[INFO] simulating digital twin on i 122, mission_id: 1216
[INFO] resampling for twin run # 4
[INFO] digital twin degradation parameters: 0.0575 11.3458 0.3226
[INFO] simulating digital twin on i 122, mission_id: 1216
[INFO] digital twin degradation parameters: 0.0575 11.3458 0.3226
[INFO] DigitalTwin mean parameter values: R0 = 0.05750  Q = 11.36  Req = 0.32044
  stop code counts: low_soc: 0 pos_err: 0  success: 4
[INFO] digital twin mission success on i: 122 mission_id: 1216
   trajectory <10> selected for TrueSystem
[INFO] simulating true system on i: 123
Bumping sigmax
[INFO] updating degradation parameter variance on i: 123
[INFO] updating degradation parameter values via random sampling on i: 123
[INFO] i: 123 mission_id: 1217 rul_hat: 13.99 flight_time: 13.25 distance: 974.42 R0: 0.05269 Q: 11.18 Req: 0.33260
[WARN] true system position error threshold exceeded on i: 123 mission_id: 1217
[INFO] forecasting degradation values: r_mu: 0.059378 q_mu: 11.205849 m_mu: 0.330668
[INFO] digital twin degradation parameters: 0.0594 10.7747 0.3348
[INFO] DigitalTwin selecting trajectory: <8> with path_time: 13.31 that meets constraint: path_time < 13.99
[INFO] simulating digital twin on i 123, mission_id: 1217
[INFO] resampling for twin run # 2
[INFO] digital twin degradation parameters: 0.0594 11.3694 0.3290
[INFO] simulating digital twin on i 123, mission_id: 1217
[INFO] resampling for twin run # 3
[INFO] digital twin degradation parameters: 0.0593 11.0234 0.3242
[INFO] simulating digital twin on i 123, mission_id: 1217
[INFO] resampling for twin run # 4
[INFO] digital twin degradation parameters: 0.0593 11.5013 0.3277
```

```
[INFO] simulating digital twin on i 123, mission_id: 1217
[INFO] digital twin degradation parameters: 0.0593 11.5013 0.3277
[INFO] DigitalTwin mean parameter values: R0 = 0.05935  Q = 11.17  Req = 0.32892
  stop code counts: low_soc: 0 pos_err: 0  success: 4
[INFO] digital twin mission success on i: 123 mission_id: 1217
   trajectory <8> selected for TrueSystem
[INFO] simulating true system on i: 124
Bumping sigmax
[INFO] updating degradation parameter variance on i: 124
[INFO] updating degradation parameter values via random sampling on i: 124
[INFO] i: 124 mission_id: 1218 rul_hat: 13.99 flight_time: 13.28 distance: 990.34 R0: 0.05468 Q: 11.41 Req: 0.32572
[INFO] success on i: 124 mission_id: 1218
[INFO] forecasting degradation values: r_mu: 0.061045 q_mu: 10.903898 m_mu: 0.337664
[INFO] digital twin degradation parameters: 0.0610 11.0767 0.3387
[INFO] DigitalTwin selecting trajectory: <10> with path_time: 13.57 that meets constraint: path_time < 13.99
[INFO] simulating digital twin on i 124, mission_id: 1218
[INFO] resampling for twin run # 2
[INFO] digital twin degradation parameters: 0.0610 11.3089 0.3478
[INFO] simulating digital twin on i 124, mission_id: 1218
[INFO] resampling for twin run # 3
[INFO] digital twin degradation parameters: 0.0610 10.7104 0.3372
[INFO] simulating digital twin on i 124, mission_id: 1218
[INFO] resampling for twin run # 4
[INFO] digital twin degradation parameters: 0.0610 10.7243 0.3278
[INFO] simulating digital twin on i 124, mission_id: 1218
[INFO] digital twin degradation parameters: 0.0610 10.7243 0.3278
[INFO] DigitalTwin mean parameter values: R0 = 0.06102  Q = 10.96  Req = 0.33786
  stop code counts: low_soc: 0 pos_err: 4  success: 0
[WARN] DigitalTwin position error threshold exceeded on i: 124 mission_id: 1218
[INFO] updating RUL from 13.99 to 12.30
[INFO] selecting new trajectory to repeat DigitalTwin simulation
[INFO] DigitalTwin selecting trajectory: <16> with path_time: 6.38 that meets constraint: path_time < 12.30
[INFO] simulating digital twin on i 124, mission_id: 1218
[INFO] resampling for twin run # 2
[INFO] digital twin degradation parameters: 0.0610 11.2345 0.3284
[INFO] simulating digital twin on i 124, mission_id: 1218
[INFO] resampling for twin run # 3
[INFO] digital twin degradation parameters: 0.0610 11.0296 0.3400
[INFO] simulating digital twin on i 124, mission_id: 1218
[INFO] resampling for twin run # 4
[INFO] digital twin degradation parameters: 0.0610 10.6530 0.3258
[INFO] simulating digital twin on i 124, mission_id: 1218
[INFO] digital twin degradation parameters: 0.0610 10.6530 0.3258
[INFO] DigitalTwin mean parameter values: R0 = 0.06098  Q = 10.91  Req = 0.33050
  stop code counts: low_soc: 0 pos_err: 0  success: 4
[INFO] digital twin mission success on i: 124 mission_id: 1218
   trajectory <16> selected for TrueSystem
[INFO] simulating true system on i: 125
Bumping sigmax
[INFO] updating degradation parameter variance on i: 125
[INFO] updating degradation parameter values via random sampling on i: 125
[INFO] i: 125 mission_id: 1219 rul_hat: 12.30 flight_time: 6.37 distance: 481.36 R0: 0.05669 Q: 11.08 Req: 0.32876
[INFO] success on i: 125 mission_id: 1219
[INFO] forecasting degradation values: r_mu: 0.063114 q_mu: 11.059706 m_mu: 0.333861
[INFO] digital twin degradation parameters: 0.0630 11.2986 0.3375
[INFO] DigitalTwin selecting trajectory: <17> with path_time: 6.03 that meets constraint: path_time < 12.30
[INFO] simulating digital twin on i 125, mission_id: 1219
[INFO] resampling for twin run # 2
[INFO] digital twin degradation parameters: 0.0631 11.1043 0.3377
[INFO] simulating digital twin on i 125, mission_id: 1219
[INFO] resampling for twin run # 3
[INFO] digital twin degradation parameters: 0.0631 11.4570 0.3281
[INFO] simulating digital twin on i 125, mission_id: 1219
[INFO] resampling for twin run # 4
[INFO] digital twin degradation parameters: 0.0631 10.8595 0.3305
```

```
[INFO] simulating digital twin on i 125, mission_id: 1219
[INFO] digital twin degradation parameters: 0.0631 10.8595 0.3305
[INFO] DigitalTwin mean parameter values: R0 = 0.06306  Q = 11.18  Req = 0.33348
  stop code counts: low_soc: 0 pos_err: 0  success: 4
[INFO] digital twin mission success on i: 125 mission_id: 1219
   trajectory <17> selected for TrueSystem
[INFO] simulating true system on i: 126
Bumping sigmax
[INFO] updating degradation parameter variance on i: 126
[INFO] updating degradation parameter values via random sampling on i: 126
[INFO] i: 126 mission_id: 1220 rul_hat: 12.30 flight_time: 6.02 distance: 433.67 R0: 0.05799 Q: 11.19 Req: 0.33091
[INFO] success on i: 126 mission_id: 1220
[INFO] forecasting degradation values: r_mu: 0.065419 q_mu: 11.037195 m_mu: 0.335967
[INFO] digital twin degradation parameters: 0.0654 11.0612 0.3324
[INFO] DigitalTwin selecting trajectory: <19> with path_time: 4.33 that meets constraint: path_time < 12.30
[INFO] simulating digital twin on i 126, mission_id: 1220
[INFO] resampling for twin run # 2
[INFO] digital twin degradation parameters: 0.0654 11.1650 0.3392
[INFO] simulating digital twin on i 126, mission_id: 1220
[INFO] resampling for twin run # 3
[INFO] digital twin degradation parameters: 0.0655 10.9035 0.3322
[INFO] simulating digital twin on i 126, mission_id: 1220
[INFO] resampling for twin run # 4
[INFO] digital twin degradation parameters: 0.0655 10.8015 0.3418
[INFO] simulating digital twin on i 126, mission_id: 1220
[INFO] digital twin degradation parameters: 0.0655 10.8015 0.3418
[INFO] DigitalTwin mean parameter values: R0 = 0.06545  Q = 10.98  Req = 0.33644
  stop code counts: low_soc: 0 pos_err: 0  success: 4
[INFO] digital twin mission success on i: 126 mission_id: 1220
   trajectory <19> selected for TrueSystem
[INFO] simulating true system on i: 127
Bumping sigmax
[INFO] updating degradation parameter variance on i: 127
[INFO] updating degradation parameter values via random sampling on i: 127
[INFO] i: 127 mission_id: 1221 rul_hat: 12.30 flight_time: 4.25 distance: 296.57 R0: 0.06024 Q: 11.10 Req: 0.33983
[INFO] success on i: 127 mission_id: 1221
[INFO] forecasting degradation values: r_mu: 0.067252 q_mu: 10.832393 m_mu: 0.337139
[INFO] digital twin degradation parameters: 0.0671 11.1279 0.3397
[INFO] DigitalTwin selecting trajectory: <16> with path_time: 6.38 that meets constraint: path_time < 12.30
[INFO] simulating digital twin on i 127, mission_id: 1221
[INFO] resampling for twin run # 2
[INFO] digital twin degradation parameters: 0.0672 11.0531 0.3339
[INFO] simulating digital twin on i 127, mission_id: 1221
[INFO] resampling for twin run # 3
[INFO] digital twin degradation parameters: 0.0672 11.6050 0.3451
[INFO] simulating digital twin on i 127, mission_id: 1221
[INFO] resampling for twin run # 4
[INFO] digital twin degradation parameters: 0.0674 11.0719 0.3370
[INFO] simulating digital twin on i 127, mission_id: 1221
[INFO] digital twin degradation parameters: 0.0674 11.0719 0.3370
[INFO] DigitalTwin mean parameter values: R0 = 0.06723  Q = 11.21  Req = 0.33894
  stop code counts: low_soc: 0 pos_err: 0  success: 4
[INFO] digital twin mission success on i: 127 mission_id: 1221
   trajectory <16> selected for TrueSystem
[INFO] simulating true system on i: 128
Bumping sigmax
[INFO] updating degradation parameter variance on i: 128
[INFO] updating degradation parameter values via random sampling on i: 128
[INFO] i: 128 mission_id: 1222 rul_hat: 12.30 flight_time: 6.37 distance: 481.39 R0: 0.06243 Q: 10.72 Req: 0.33668
[INFO] success on i: 128 mission_id: 1222
[INFO] forecasting degradation values: r_mu: 0.069516 q_mu: 10.442759 m_mu: 0.343006
[INFO] digital twin degradation parameters: 0.0696 10.8439 0.3491
[INFO] DigitalTwin selecting trajectory: <16> with path_time: 6.38 that meets constraint: path_time < 12.30
[INFO] simulating digital twin on i 128, mission_id: 1222
[INFO] resampling for twin run # 2
```

```
[INFO] digital twin degradation parameters: 0.0695 10.5704 0.3407
[INFO] simulating digital twin on i 128, mission_id: 1222
[INFO] resampling for twin run # 3
[INFO] digital twin degradation parameters: 0.0695 10.8064 0.3423
[INFO] simulating digital twin on i 128, mission_id: 1222
[INFO] resampling for twin run # 4
[INFO] digital twin degradation parameters: 0.0694 9.8946 0.3442
[INFO] simulating digital twin on i 128, mission_id: 1222
[INFO] digital twin degradation parameters: 0.0694 9.8946 0.3442
[INFO] DigitalTwin mean parameter values: R0 = 0.06948  Q = 10.53  Req = 0.34408
  stop code counts: low_soc: 0 pos_err: 0  success: 4
[INFO] digital twin mission success on i: 128 mission_id: 1222
   trajectory <16> selected for TrueSystem
[INFO] simulating true system on i: 129
Bumping sigmax
[INFO] updating degradation parameter variance on i: 129
[INFO] updating degradation parameter values via random sampling on i: 129
[INFO] i: 129 mission_id: 1223 rul_hat: 12.30 flight_time: 6.37 distance: 481.39 R0: 0.06412 Q: 10.60 Req: 0.33337
[INFO] success on i: 129 mission_id: 1223
[INFO] forecasting degradation values: r_mu: 0.072219 q_mu: 10.921814 m_mu: 0.341122
[INFO] digital twin degradation parameters: 0.0722 10.6670 0.3410
[INFO] DigitalTwin selecting trajectory: <18> with path_time: 11.78 that meets constraint: path_time < 12.30
[INFO] simulating digital twin on i 129, mission_id: 1223
[INFO] resampling for twin run # 2
[INFO] digital twin degradation parameters: 0.0722 10.9912 0.3425
[INFO] simulating digital twin on i 129, mission_id: 1223
[INFO] resampling for twin run # 3
[INFO] digital twin degradation parameters: 0.0723 11.3424 0.3433
[INFO] simulating digital twin on i 129, mission_id: 1223
[INFO] resampling for twin run # 4
[INFO] digital twin degradation parameters: 0.0721 11.0551 0.3474
[INFO] simulating digital twin on i 129, mission_id: 1223
[INFO] digital twin degradation parameters: 0.0721 11.0551 0.3474
[INFO] DigitalTwin mean parameter values: R0 = 0.07222  Q = 11.01  Req = 0.34356
  stop code counts: low_soc: 0 pos_err: 4  success: 0
[WARN] DigitalTwin position error threshold exceeded on i: 129 mission_id: 1223
[INFO] updating RUL from 12.30 to 10.30
[INFO] selecting new trajectory to repeat DigitalTwin simulation
[INFO] digital twin rul_hat: 2.28 does not meet the threshold: 10.00 on i,mission 129,1223 with fail_count 1
[INFO] DigitalTwin selecting trajectory: <7> with path_time: 0.91 that meets constraint: path_time < 2.28
[INFO] simulating digital twin on i 129, mission_id: 1223
[INFO] resampling for twin run # 2
[INFO] digital twin degradation parameters: 0.0722 10.5579 0.3347
[INFO] simulating digital twin on i 129, mission_id: 1223
[INFO] resampling for twin run # 3
[INFO] digital twin degradation parameters: 0.0722 11.0520 0.3382
[INFO] simulating digital twin on i 129, mission_id: 1223
[INFO] resampling for twin run # 4
[INFO] digital twin degradation parameters: 0.0721 11.2521 0.3389
[INFO] simulating digital twin on i 129, mission_id: 1223
[INFO] digital twin degradation parameters: 0.0721 11.2521 0.3389
[INFO] DigitalTwin mean parameter values: R0 = 0.07215  Q = 10.98  Req = 0.33977
  stop code counts: low_soc: 0 pos_err: 0  success: 4
[INFO] digital twin mission success on i: 129 mission_id: 1223
   trajectory <7> selected for TrueSystem
[INFO] digital twin rul_hat: 2.28 does not meet the threshold: 10.00 on i,mission 129,1223 with fail_count 2
[INFO] simulating true system on i: 130
Bumping sigmax
[INFO] updating degradation parameter variance on i: 130
[INFO] updating degradation parameter values via random sampling on i: 130
[INFO] i: 130 mission_id: 1224 rul_hat: 2.28 flight_time: 0.91 distance: 69.47 R0: 0.06669 Q: 10.74 Req: 0.32874
[INFO] success on i: 130 mission_id: 1224
[INFO] forecasting degradation values: r_mu: 0.074234 q_mu: 10.007447 m_mu: 0.343253
[INFO] digital twin degradation parameters: 0.0742 10.1759 0.3398
[INFO] DigitalTwin selecting trajectory: <7> with path_time: 0.91 that meets constraint: path_time < 2.28
```

```
[INFO] simulating digital twin on i 130, mission_id: 1224
[INFO] resampling for twin run # 2
[INFO] digital twin degradation parameters: 0.0743 9.7480 0.3398
[INFO] simulating digital twin on i 130, mission_id: 1224
[INFO] resampling for twin run # 3
[INFO] digital twin degradation parameters: 0.0744 9.9215 0.3455
[INFO] simulating digital twin on i 130, mission_id: 1224
[INFO] resampling for twin run # 4
[INFO] digital twin degradation parameters: 0.0742 9.6215 0.3409
[INFO] simulating digital twin on i 130, mission_id: 1224
[INFO] digital twin degradation parameters: 0.0742 9.6215 0.3409
[INFO] DigitalTwin mean parameter values: R0 = 0.07426  Q = 9.87  Req = 0.34151
  stop code counts: low_soc: 0 pos_err: 0  success: 4
[INFO] digital twin mission success on i: 130 mission_id: 1224
   trajectory <7> selected for TrueSystem
[INFO] digital twin rul_hat: 2.28 does not meet the threshold: 10.00 on i,mission 130,1224 with fail_count 3
[INFO] simulating true system on i: 131
Bumping sigmax
[INFO] updating degradation parameter variance on i: 131
[INFO] updating degradation parameter values via random sampling on i: 131
[INFO] i: 131 mission_id: 1225 rul_hat: 2.28 flight_time: 0.91 distance: 69.46 R0: 0.06904 Q: 10.56 Req: 0.33396
[INFO] success on i: 131 mission_id: 1225
[INFO] forecasting degradation values: r_mu: 0.076899 q_mu: 10.295440 m_mu: 0.339436
[INFO] digital twin degradation parameters: 0.0770 9.7815 0.3414
[INFO] DigitalTwin selecting trajectory: <7> with path_time: 0.91 that meets constraint: path_time < 2.28
[INFO] simulating digital twin on i 131, mission_id: 1225
[INFO] resampling for twin run # 2
[INFO] digital twin degradation parameters: 0.0770 10.3125 0.3476
[INFO] simulating digital twin on i 131, mission_id: 1225
[INFO] resampling for twin run # 3
[INFO] digital twin degradation parameters: 0.0769 10.2161 0.3418
[INFO] simulating digital twin on i 131, mission_id: 1225
[INFO] resampling for twin run # 4
[INFO] digital twin degradation parameters: 0.0770 9.9935 0.3262
[INFO] simulating digital twin on i 131, mission_id: 1225
[INFO] digital twin degradation parameters: 0.0770 9.9935 0.3262
[INFO] DigitalTwin mean parameter values: R0 = 0.07696  Q = 10.08  Req = 0.33924
  stop code counts: low_soc: 0 pos_err: 4  success: 0
[WARN] DigitalTwin position error threshold exceeded on i: 131 mission_id: 1225
[INFO] updating RUL from 2.28 to 0.28
[INFO] selecting new trajectory to repeat DigitalTwin simulation
[INFO] digital twin rul_hat: -0.66 does not meet the threshold: 10.00 on i,mission 131,1225 with fail_count 4
[INFO] returning empty table
[INFO] no more valid trajectories. ending simulation.
[INFO] no more valid trajectories. ending simulation.
```

********** end of simulation code

test sim digital twin (for testing)

```
i = 1;
sys = "DigitalTwin";
octomodel.sampletime = true_sample_rate;
sprintf('[INFO] simulating digital twin on mission: %d', i);
tic
sim('digitaltwin1c.slx');
toc
```

```
clear('trajectory', 'battery_actual', 'battery_observed', 'ctrl_err', 'current', 'current_rs',
```

test sim true system (for testing)

```
i = 1;
sys = "TrueSystem";
octomodel.sampletime = true_sample_rate;
sprintf('[INFO] simulating true system on mission: %d', i);
tic
sim('truesystem.slx');
toc
```

```
updated = true;
while updated
    load_trajectory;
    if(isempty(trajectory))
        disp("[INFO] no more valid trajectories. ending simulation.")
        break;
    end
    if trajectory.path_time > rul_hat
        fprintf("[INFO] DigitalTwin selecting trajectory: <%d> with path_time: %.2f to explore
    else
        fprintf("[INFO] DigitalTwin selecting trajectory: <%d> with path_time: %.2f that meets
    end
    sys = "DigitalTwin";
    octomodel.sampletime = twin_sample_rate;
    for twin_ctr=3:twin_count
        fprintf('[INFO] simulating digital twin on i %d, mission_id: %d\n', i, mission_id)
        out = sim('digitaltwin1c.slx');
        %        get the output from each parallel worker
        times(twin_ctr) = flight_time.Data(end);
        vs(twin_ctr) = battery_actual.Data(end, 1);
        socs(twin_ctr) = battery_actual.Data(end, 2);
        r0s(twin_ctr) = battery_actual.Data(end, 3);
        qs(twin_ctr) = battery_actual.Data(end, 6);
        ms(twin_ctr) = motors.Data(end, 1);
        errs(twin_ctr) = mean(euclidean_pos_err);
        dist(twin_ctr) = calculatedistance([pos_actual.Data(:,1) pos_actual.Data(:,2)]);
        degs(:, twin_ctr) = [batterytwin.R0 batterytwin.Q Motortwin2.Req]';
        codes(:, twin_ctr) = [any(stop_code.Data(:,1)); any(stop_code.Data(:,2)); any(stop_code
```

write digital twin parameters to db

```
        write_twin_params_data;
```

resample the degradation parameters for the next digital twin simulation

```
        if twin_count > 1 && twin_ctr < twin_count
           fprintf('[INFO] resampling for twin run # %d', twin_ctr + 1);
           if i > lookback
                batterytwin.R0 = normrnd(r_mu, r_var);
                batterytwin.Q = normrnd(q_mu, q_var);
```

```
                Motortwin2.Req = normrnd(m_mu, m_var);
            else
                batterytwin.R0 = max(abs(normrnd(rdeg(i), r_var)), .00075);
                batterytwin.Q = min(abs(normrnd(qdeg(i), q_var)), 15.5);
                Motortwin2.Req = max(abs(normrnd(mdeg(i), m_var)), .001);
            end
        end
        fprintf("[INFO] digital twin degradation parameters: %.4f\t%.4f\t%.4f", batterytwin.R0,
    end

    low_soc = sum(codes(1,:) == 1);
    pos_err = sum(codes(2,:) == 1);
    success = sum(codes(3,:) == 1);
    fprintf("[INFO] DigitalTwin mean parameter values: R0 = %.5f\t Q = %.2f\t Req = %.5f\n\t st
```

update rul

```
    if low_soc == 1
        fprintf('[WARN] DigitalTwin low soc threshold exceeded once, adjusting rul_hat')
        rul_hat = rul_hat - .5;
    end
    if pos_err == 1
        fprintf('[WARN] DigitalTwin pos err threshold exceeded once, adjusting rul_hat')
        rul_hat = rul_hat - 1.0;
    end

    if low_soc > 1
        fprintf('[WARN] DigitalTwin low soc threshold exceeded on i: %d\tmission_id: %d\n', i,
        temp = mean(times(:)) - 1;
        res = max(temp, rul_hat - 2);
        fprintf('[INFO] updating RUL from %.2f to %.2f', rul_hat, res)
        rul_hat = mean(times(:)) - 1; % rul is now 1 minute less than the digital twin flight t
        updated = true;
    end

    if pos_err > 1
        fprintf('[WARN] DigitalTwin position error threshold exceeded on i: %d\tmission_id: %d\
        temp = mean(times(:)) - 1;
        res = max(temp, rul_hat - 2);
        fprintf('[INFO] updating RUL from %.2f to %.2f', rul_hat, res)
        rul_hat = mean(times(:)) - 1; % rul is now 1 minute less than the digital twin flight t
        updated = true;
    end

    if success >= 3 && pos_err < 2 && low_soc < 2
        fprintf('[INFO] digital twin mission success on i: %d\tmission_id: %d\n   trajectory <%
        updated = false;
        if mean(times(:)) - 1 > rul_hat
            fprintf('[INFO] new RUL update is available, %.2f replaces %.2f\n', mean(times(:))
            rul_hat = mean(times(:)) - 1;
        end
    end
    if updated
        fprintf('[INFO] selecting new trajectory to repeat DigitalTwin simulation')
```

```
    end

    % otherwise, end of life was never reached so the current rul estimate
    % is the best estimate

    if rul_hat <= rul_threshold
        fail_count = fail_count + 1;
        fprintf('[INFO] digital twin rul_hat: %.2f does not meet the threshold: %.2f on i,missi
        if fail_count == 10
            fprintf('[INFO] fail_count reached limit. Stopping simulation.')
            end_sim = 1;
            break;
        end
    end
    clear('battery_actual', 'battery_observed', 'ctrl_err', 'current', 'current_rs', 'euclidear
end
```

```
[INFO] DigitalTwin selecting trajectory: <10> with path_time: 13.57 that meets constraint: path_time < 17.16
[INFO] simulating digital twin on i 67, mission_id: 1161
[INFO] resampling for twin run # 4
[INFO] digital twin degradation parameters: 0.0059 13.8051 0.2914
[INFO] simulating digital twin on i 67, mission_id: 1161
[INFO] digital twin degradation parameters: 0.0059 13.8051 0.2914
[INFO] DigitalTwin mean parameter values: R0 = 0.00544  Q = 13.56  Req = 0.29013
  stop code counts: low_soc: 0 pos_err: 0  success: 4
[INFO] digital twin mission success on i: 67 mission_id: 1161
   trajectory <10> selected for TrueSystem
```